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CALIFORNIA FISH AND GAME

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SACRAMENTO

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THE SAND SHARK, *CARCHARIAS FEROX* (RISSO), IN CALIFORNIA[1]

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Marine Resources Operations
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On November 2, 1962, a small lampara boat, the *Sandy Boy*, skippered by Tom Trama, landed at a Terminal Island cannery a catch of jack mackerel (*Trachurus symmetricus*), taken about the middle of the north side of San Clemente Island. On deck, taken in the same haul, was a shark perhaps 10 feet long. I saw it only briefly, just long enough to realize it was a kind I had never seen before; then the boat departed for the San Pedro fish markets, intending to unload the shark there by hoist. I arrived at the markets a short time later, and found that, due to a misunderstanding, the shark had been butchered and sold for food. I retrieved the head from the trash barrel, but was unable to save any trimmings or internal organs.

Fortunately, the shapes of the teeth and their arrangement in the jaws were so distinctive I was able to identify the shark without any doubt as a sand shark, *Carcharias ferox*. This shark has been known to most recent ichthyologist under the generic name, *Carcharias*, which was established by a ruling of the International Commission on Zoological Nomenclature in 1912. However, in 1961, a recommendation (currently pending) was made that the name be changed to *Odontaspis*. This was in part because, while ichthyologist are concerned with at most seven, and possibly with only two, living species, paleontologists are dealing with over 50 species, and they have almost universally used the name *Odontaspis* since Agassiz proposed it in 1838.

C. ferox was first described from the Mediterranean in 1810 and most records are from there, with a few from the adjacent eastern Atlantic. There is at least one record from Madeira of a specimen taken in 1941 (Maul, 1955). Whitley (1950) reported two occurrences for New South Wales, Australia, one in 1947 and one in 1948. There are no other records.

Since local gillnetters probably catch many species they do not regard as particularly rare and therefore do not bother saving, I eventually wrote to four such fishermen who had previously saved us specimens, describing this species and asking them to watch out for it. On January 10, 1963, one of the four, Gene Hachez of Costa Mesa, fishing with shark gill nets from the boat *Sea Spray*, caught a different-looking shark off San Onofre and recognized it from my description. He has been fishing sharks for 5 years and does not remember having seen this kind before. He is interested in unusual species and would be apt to

[1] Submitted for publication July 1963.

FIGURE 1. Side view of 5-foot *Carcharias ferox* (CAS 27023) from San Onofre, California. Photograph by Jack W. Schott, 1963.

notice anything out of the ordinary. The specimen was saved for us through the courtesy of Delaney Bros. Market, in Newport Beach.

The Hachez shark, a male approximately 5½ feet long and weighing 61 pounds, was stout-bodied and full-bellied (Figure 1). Whitley's photograph shows the same shape, and he made the apt comparison, "paunch rotund 'like a cow's belly'." This was particularly noticeable in the *Sandy Boy* specimen. Several illustrators have erroneously shown *C. ferox* as a long, slim shark with an elongate tail, possibly copying Bonaparte (1841). Lozano Ray (1928) reproduced Bonaparte's figure, and said he got all his data from other authors, especially Agassiz (1836), Bonaparte (1841), and Moreau (1881). Moreau saw a head and large whole animal; however, he perhaps also took his proportions from Bonaparte's drawing or description, or from another source, as both he and Lozano Rey said the body was elongate, its length equalling eight times its height, and the tail equalling one-third total length. In my specimen (Figure 1) the body height at the first dorsal insertion goes between five and five and one-half times, and the tail about four times, into the total length. Whitley's photograph shows the same proportions.

Another point of disagreement is in the placement of the dorsal fins. Moreau said the first dorsal is inserted a little behind the posterior angle of the pectorals, and Bonaparte's drawing shows it only a very little behind. The second dorsal, according to Moreau, ends above the anterior third of the anal, and Bonaparte's drawing agrees. Both my photograph and Whitley's show the first dorsal situated about one-fourth of the distance between the posterior of the pectorals and the pelvic insertion, and the second dorsal well in front of the anal. Measurements and proportions of the San Onofre specimen appear in Table 1, modified from Rosenblatt and Baldwin (1958).

Still another confusing point, needing clarification, is color. Risso's original description was of a reddish animal with large black spots on the back. Moreau (1881), Tortonese (1956), and other writers described an animal with smiliar coloration and spotting. In some cases, writers probably did not see a specimen but copied information given by others. Also, spotting may be a juvenile pattern. However, Moreau

TABLE 1

Measurements of Body Parts, and Proportions in Length Without Caudal, of the San Onofre **Carcharias ferox**

	Measurement (mm)	*Proportion*
Total length	1693	
Length without caudal	1245	
Trunk width over pectoral origins	120	(.096)
Trunk height at pectoral origins	220	(.177)
Head length	429	(.345)
Head width at angles of mouth	111	(.089)
Interorbital width	91	(.073)
Head width at outer ends nostrils	98	(.079)
Mouth width	99	(.080)
Mouth length (lower jaw)	94	(.076)
Fleshy orbit diameter	33	(.027)
Preoral length	121	(.097)
Prenarial length	106	(.085)
Nostril length	22	(.018)
Internarial distance	104	(.084)
Length labial fold	32	(.026)
Length 1st gill slit	89	(.071)
Length 2nd gill slit	89	(.071)
Length 3rd gill slit	86.5	(.069)
Length 4th gill slit	86.5	(.069)
Length 5th gill slit	86.5	(.069)
Origin pectoral to base 1st gill slit	104	(.084)
Height 1st dorsal (perpendicular)	116	(.093)
Length anterior margin 1st dorsal	180	(.145)
Length 1st dorsal base	154	(.124)
Height posterior margin 1st dorsal	116	(.093)
Length free rear tip 1st dorsal	48	(.039)
Height 2nd dorsal (perpendicular)	84	(.067)
Length 2nd dorsal base	101	(.081)
Length free rear tip 2nd dorsal	46	(.037)
Height anal (perpendicular)	83	(.067)
Length anterior margin anal	111	(.089)
Length anal base	78	(.063)
Length free rear tip anal	42	(.034)
Length pelvic	145	(.116)
Length pelvic base	129	(.104)
Pelvic origin to anal origin	264	(.212)
Pelvic origin to pectoral origin	489	(.393)
Length anterior margin pectoral	222	(.178)
Length posterior margin pectoral	77	(.062)
Length distal margin pectoral	145	(.116)
Length upper caudal lobe	438	(.352)
Length lower caudal lobe	168	(.135)
Tip of snout to origin 1st dorsal	560	(.450)
Tip of snout to origin 2nd dorsal	1029	(.827)
Tip of snout to origin anal	1138	(.914)
Tip of snout to origin pelvic	894	(.718)
Tip of snout to origin pectoral	417	(.335)
Origin 1st dorsal to origin 2nd dorsal	457	(.367)
Origin 2nd dorsal to upper tail base	220	(.177)
Origin anal to lower tail base	129	(.104)

and Tortonese at least saw large specimens. On the other hand, Garmen (1913) said "black and sides ashy brown, lower surfaces lighter." The 5-foot 6-inch Australian specimen, which was entire (the other being only a jaw), the 6-foot 4-inch Madeira specimen, and my two specimens were almost uniform light grey above, and slightly lighter below. Some darkening of the fins was reported in the first two but was not noticeable in mine. Light spotting was described in *C. taurus* by Bigelow and Schroeder (1948) and others.

Whitley said of his specimen, "No visible spiracle"; but it was definitely visible, though small, on both my specimens. Other writers described it as present but small.

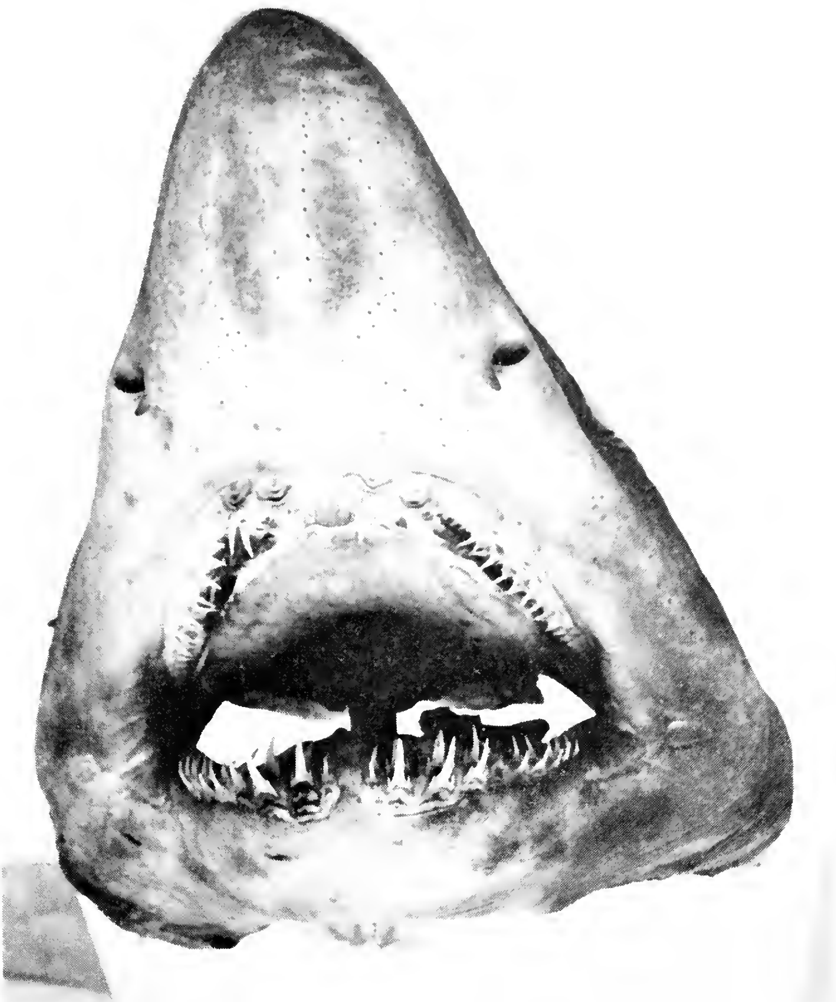

FIGURE 2. Head of 10-foot *Carcharias ferox* (CAS 27022) from San Clemente Island, California. *Photograph by Jack W. Schott, 1963.*

The most distinctive characteristic of the species is the unique teeth and their arrangement. They are narrow and fanglike (Figure 2), most similar to those of the salmon shark (*Lamna ditropis*) among our common local forms, but even more pronouncedly needlelike. Each tooth consists of a long, central portion, with (usually) two or more small cusps or denticles at the base on either side. Most authors have given five as the typical number of cusps. Lozano Rey (1928) said that one pair is occasionally missing near the symphysis or near the posterior angle of the jaw, making the total number on these teeth three; and Moreau saw a large individual (12½ feet) in which a pair was missing on most teeth, and speculated this might be a matter of age. Careful inspection of my larger (San Clemente Island) specimen, in which accurate counts were possible because the jaw was removed from the head and cleaned, revealed that 39 out of 54 teeth in the upper jaw had seven cusps, 13 had five, and 2 had three; in the lower jaw, 22 had seven, 14 had five, 1 had four, and 5 had three. A partial count on the jaw of the smaller (San Onofre) specimen revealed that most teeth had five cusps, several had seven, six, or three.

TABLE 2

Tooth Cusp Counts for **Carcharias ferox**, Starting at the Symphysis

San Clemente Island Specimen

Upper left: 5, 5, 5, 7, 5, 7, 7, 7, 7, 7, 7. 7, 7. 7. 7, 7, 7. 7, 7, 7. 7. 7, 7, 7, 5, 5, 3.

Upper right: 5, 5, 5, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7. 7, 7, 7, 7, 7, 7, 7, 7, 5, 5, 5, 5, 3.

Lower left: 5, 5, 5, 5, 5, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 5. 5, 3, 3, 3.

Lower right: 5, 4, 5. 5. 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 5, 5, 5, 5, 3. 3.

San Onofre Specimen*

Upper left: 5, 5, 5, 5. 5, 5, 5, 5, 5, 5, 5, 5, 6, 7, 5, 5, 5, 5.

Upper right: 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 6, 7, 5, 5, 5.

Lower left: 5, 5, 5, 5, 5, 6, 5, 5, 5, 5. 5, 5, 5, 5.

Lower right: 3, 3, 3, 5, 5, 5, 5, 5, 5, 5, 5, 5.

* It was not possible to make counts on the posterior teeth of the San Onofre specimen. Accurate counts were possible on all teeth of the San Clemente specimen.

TABLE 3

Median Length of Each **Carcharias ferox** Tooth, in Millimeters, Starting at the Symphysis

San Clenmente Island Specimen (CAS 27022)

Upper left: 9.2, 20.4, 20.3, 8.6, 6.9, 6.9, 7.3, 11.8, 14.7, 14.4, 13.7, 12.9, 11.5, 9.8, 9.4, 7.6, 7.2, 6.3, 5.0, 4.9, 4.7, 4.0, 4.0, 2.9, 2.9, 2.6, 2.1.

Upper right: 8.8, 20.9, 20.4, 8.8, 6.8, 6.6, 7.7, 12.5, 14.4, 14.5, 13.5, 12.4, 11.4, 10.3, 8.8, 7.0, 5.9, 5.6, 5.3, 4.7, 4.7, 3.9, 3.5, 3.4, 3.0, 2.3, 1.8.

Lower left: 12.0, 23.3, 25.4, 19.3, 15.1, 13.5, 13.4, 12.5, 11.4, 10.0, 8.4, 7.5, 6.0, 4.9, 4.4, 4.2, 3.6, 2.6, 2.3, 2.0, 1.3.

Lower right: 11.0, 22.8, 25.7, 18.3, 15.0, 13.7, 13.0, 13.0, 11.2, 10.0, 8.6, 7.7, 6.4, 5.7, 4.5, 4.0, 3.2, 3.0, 2.0, 2.0, 1.7.

San Onofre Specimen (CAS 27023)*

Upper left: 4.0, 9.7, 9.4, 4.1, 4.1, 3.1, 3.2, 5.9, 6.6, 6.3, 6.3, 5.9, 4.8, 4.6, 3.8.

Upper right: 3.4, 9.9, 9.9, 4.5, 3.7, 2.5, 4.0, 5.5, 6.0, 6.6, 6.3, 6.3, 5.0, 4.3, 4.1.

Lower left: 5.2, 11.3, 12.5, 9.3, 7.1, 6.6, 6.2, 6.0, 5.4, 5.0, 4.4, 3.6, 2.8, 2.5, 1.7.

Lower right: 5.8, 10.7, 10.8, 8.8, 5.8, 5.8, 5.2, 5.3, 5.2, 5.0, 4.5, 3.6, 2.8, 2.5, 1.8.

* It was not possible to measure the teeth in this specimen with accuracy beyond the 15th.

The arrangement of teeth in the jaw is also unique. There is a gap at the upper jaw symphysis, then on each side there is a small tooth, followed by two large ones, then four small ones, then medium-sized ones decreasing posteriorly. In the lower jaw, there is a gap at the symphysis, followed by a small tooth, two large teeth, then teeth gradually decreasing in size. Tooth numbers on each side of the jaw, as given by different writers, vary from 23/18 to 27/24 (upper/lower). In the San Onofre specimen, the count was 27/20 on one side, 27/21 on the other; in the San Clemente Island specimen, it was 27/21 on each side. Measurements of the central tooth-prongs appear in Table 3.

A prominent feature, evident in Whitley's photograph and pronounced in my second specimen, is a tendency for the jaws to protrude (Figure 1).

In both specimens, the roof of the mouth was dusky, becoming abruptly white posteriorly.

In the Mediterranean, this shark is apparently not very common; perhaps it appears to be rare because it lives in fairly deep water ("*in profondita*," according to Tortonese) and because it is not particularly sought as a market species. The Madeiran specimen reportedly was caught "at considerable depth." The two Australian specimens were taken by trawlers at 70 and 75 fathoms, respectively. The 10-foot Californian specimen was netted only 100 to 200 yards offshore, in 7 to 8 fathoms of water. However, the north shore of San Clemente Island shoals rapidly, and the 100-fathom line is a mile or less offshore. The San Onofre specimen was taken about 2 to 4 miles offshore, in 50-55 fathoms.

A gillnet fisherman reported capturing a possible third Californian individual. He said it was a very large female, taken close to shore in 12 fathoms of water at Pyramid Cove, at the east end of San Clemente Island, on April 5, 1963. Here, the 50-fathom line is about 2 miles offshore, the 100-fathom line about 3 miles. It was described as having teeth like a bonito shark (*Isurus glaucus*), no precaudal keel, and (in answer to my question) a prominent belly. Since it was so large, and had little apparent market value, it was dumped overboard. I have little doubt that it was a third *Carcharias ferox*, and have hopes that still others may turn up in this vicinity.

The two Californian specimens have been deposited in the California Academy of Sciences, San Francisco (CAS 27022 and 27023).

ACKNOWLEDGMENTS

I wish to thank those through whose kindness I obtained these specimens. Also, I am very indebted to W. I. Follett, California Academy of Sciences, for help with the literature and other matters, and for taking the tooth measurements and cusp counts. I wish to thank J. E. Fitch and J. L. Baxter, California Department of Fish and Game, for assistance with the manuscript, and J. W. Schott for taking the photographs.

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AN EXPERIMENTAL STUDY TO CONTROL OYSTER DRILLS IN TOMALES BAY, CALIFORNIA [1]

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INTRODUCTION

The primary purpose of this study was to evaluate the feasibility of chemically controlling oyster drills in Tomales Bay. Oyster predators have cost oyster producing countries millions of dollars annually. Oyster mortality due to drilling snails can reduce yields to unprofitable levels; therefore, the study and control of these pests is a major concern. In the State of Washington, some oyster beds in Puget Sound (Samish and Oyster Bays) have been abandoned because of severe depredation by drills (Chapman and Banner, 1949; Cahn, 1950).

A series of drill trap studies was made in the spring of 1962. In addition, a field study of the status of drilling snails in the bay was made to provide information basic to evaluating chemical pest control methods.

The history of oyster drills in California is similar to that of all coastal regions of the world where oysters have been transplanted from drill-infested areas without adequate pest control measures.

Eastern drills, *Urosalpinx cinerea*, were introduced to California soon after completion of the transcontinental railroad made shipment of eastern oysters (*Crassostrea virginica*) possible. The first of these oysters were planted in San Francisco Bay, and later, after 1870 in Tomales Bay. Eastern drills contained in these shipments became established in oyster culture areas in upper portions of the bay. Japanese drills, *Ocenebra* (=*Tritonalia*) *japonica*, were introduced with seed shipments of Pacific giant oysters, *Crassostrea gigas*, to the State of Washington after 1900 (Galtsoff, 1930), and were reported in a shipment to California in 1930. However, the latter shipment was condemned and not planted (Bonnot, 1935).

Bonnot (1935) mentioned that eastern drills and limpets, *Crepidula fornicata*, were abundant in oyster culture areas of Tomales Bay, but that Japanese drills had not yet been introduced.

Although inspection of Japanese seed oysters was initiated in 1935, my 1962 survey of Tomales Bay Oyster Company beds showed that Japanese drills are now present, but not nearly so abundant as eastern drills.

Hanna (1939) recorded eastern drills in San Francisco Bay as late as 1928, and cited Bonnot's conclusion that Japanese drills had not entered California.

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[1] Submitted for publication June 1963. Study performed by service agreement between California Department of Fish and Game and University of the Pacific, and submitted in partial fulfillment of the requirements for the degree of Master of Arts.

Smith and Gordon (1948) reported that *Urosalpinx* is "fairly common" in Elkhorn Slough (opening into Monterey Bay), and Keen (1937) and Johnson and Snook (1927) reported geographical distributions for the species (lat. 34-38° N., and San Francisco to San Diego, respectively). These should be checked as there is no recent evidence of living drills in Elkhorn Slough, although they are common in south San Francisco Bay. MacGinitie (1935), in an ecological study of Elkhorn Slough, mentioned the danger of introducing oyster pests, but did not record them.

DISTRIBUTION AND ACTIVITY OF DRILLS

At Tomales Bay I found eastern drills, Japanese drills, angular unicorn-shells (*Acanthina spirata*), and wrinkled thais (*Thais lamellosa*). The latter two are native species. *T. lamellosa* was represented by a single specimen 56 mm long. The three other species (Figure 1) were abundant, but limited to the vicinity of Tomales Bay Oyster Company.

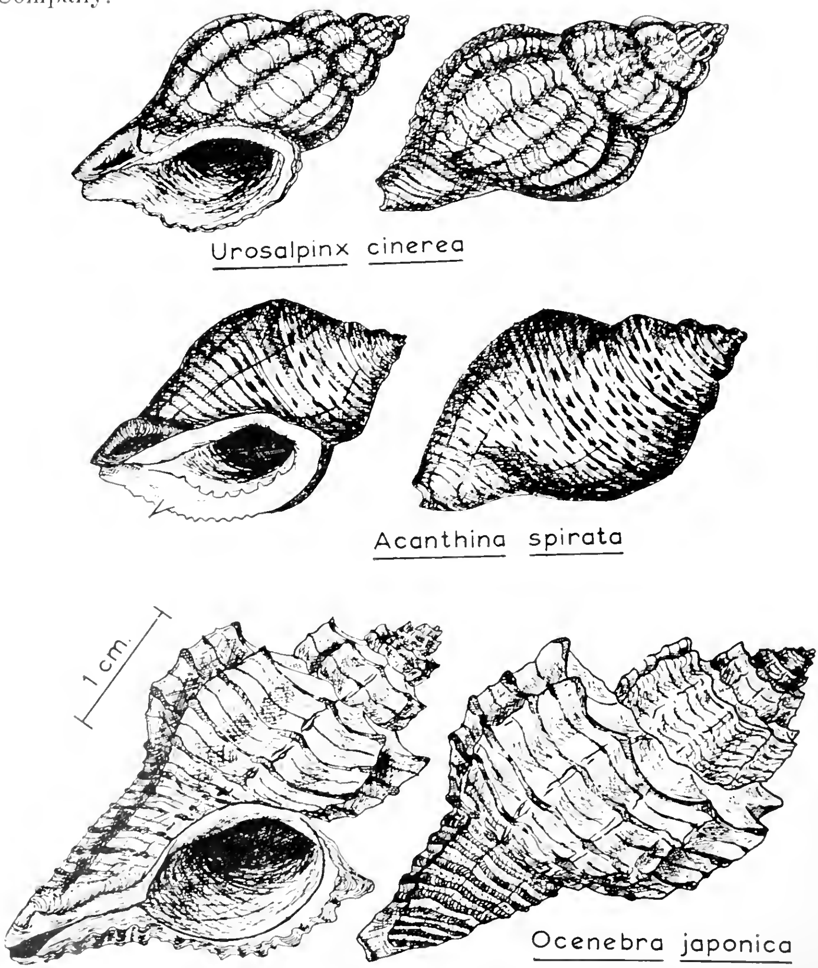

FIGURE 1. Dorsal (right) and ventral (left) views of drills.

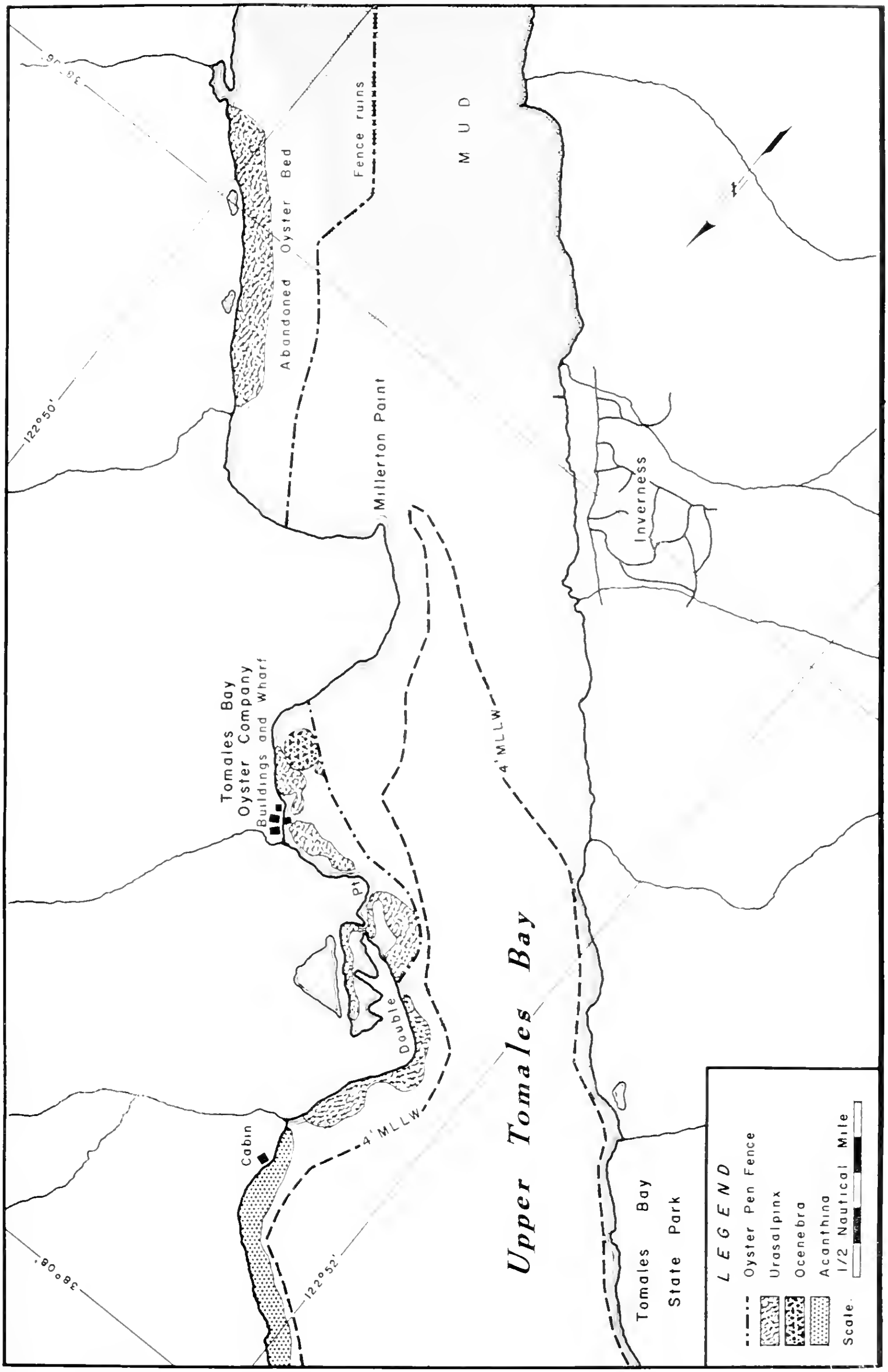

FIGURE 2. Upper Tomales Bay, California.

Urosalpinx was throughout the oyster beds and along the shore to one-half mile north of the oyster company grounds (Figure 2). This was the only species along the shore of the abandoned oyster beds east of Millerton Point. *Ocenebra* was found only on active beds of the oyster company. It was most abundant in the southwest corner of the area bounded by fencing, but was occasionally found in all areas used for oyster culture. *Acanthina* was the most widely distributed in the bay; it does not constitute as great a hazard to oyster culture as eastern and Japanese drills. *Acanthina* and the native rock snail, *Thais emarginata*, were found at Nick's Cove, 6 miles closer to the mouth of the bay than Millerton Point.

Quantitative Distribution

Most attempts to determine the number of drills in a particular area are based upon plots of trap catches made over a period of time. Previous studies have shown the danger of assuming that random samples are being removed from the population (Carriker, 1955). During fall and winter, many drills, especially *Urosalpinx*, remain buried in the substrate with only their siphon tips projecting. During spring and summer, females are easily trapped; they move to bait-shells and tend to climb up to deposit egg-cases. Cole (1942) found they are not as easily dislodged as males when traps are retrieved.

In upper Tomales Bay, drills were definitely more dense in areas used for oyster culture. When handpicking drills, the catch-per-day increased as they became progressively more active during spring and summer. Relative numbers of three species were obtained by removing all snails from a 300 square foot plot in the northern portion of the oyster beds near Double Point on July 13, 1961. On that day, 3,029 *Urosalpinx*, 46 *Acanthina*, and 11 *Ocenebra* were collected, and next day 383, 1, and 3, respectively. These were collected from barnacle-encrusted rocks isolated by bare mud on three sides and in concentrations comparable to areas spread with old oyster shells to make firm soft mud bottoms.

In the time spent collecting 50 *Ocenebra* from oyster clusters and shell piles, between 100 and 200 *Urosalpinx* could be gathered. One large shell pile, bordered on the southwest by fencing and on the northeast by the Double Point bed was also heavily infested with eastern drills. One 4- x 4-foot plot yielded 95 eastern drills and 6 Japanese drills in June 1961.

A similar-sized plot, just south of Nick's Cove was cleared of drills on July 26, and again 2 days later. The first day's catch was 478 *Acanthina*; 47 were taken on the second trip. There were no exotics, and *Thais emarginata* was not represented there although it was found a short distance north.

In 1961, 50 to 100 Japanese drills could be collected in about 2 hours on the southwest portion of the oyster company beds in clusters of oysters and small shell piles. They were less abundant in oyster clusters than shell piles. Approximately one oyster cluster in 20 harbored two or three drills. These observations apply to a bed of 3-year-old oysters on the southwest corner of the property bounded by Millerton Point and the oyster pen fence. Other portions of the oyster culture area

were believed to have Japanese drills in a density comparable to a 300-square-foot plot where 14 were collected in 2 days.

Acanthina usually was not found on oysters or in shell piles unless barnacles also were there. *Acanthina* was more often on high, rocky ground near shore. During August 1961, I found between 10 and 40 individuals under each barnacle-encrusted rock in an area a mile north of the beds.

Cole (1942) and Orton and Lewis (1931) have demonstrated the progressive replacement of English drills, *Ocenebra eracina*, by *Urosalpinx* in the River Blackwater, England. At the Tomales Bay Oyster Company, *Acanthina* competes with *Urosalpinx* for food and space; the latter's place is taken by *Thais emarginata* at Nick's Cove. Between the two areas *Acanthina* enjoys relative abundance.

Size Distribution

Length measurements were made on 116 male and 144 female *Ocenebra* taken from the southwest corner of the oyster beds and 611 male and 987 female *Urosalpinx* taken from the 300-square-foot plot in the more northerly beds near Double Point. The shell height of male Japanese drills ranged from 20 to 43 mm and females 20 to 45 mm, averaging 29.0 mm and 31.0 mm respectively. Male eastern drills ranged from 16 to 29 mm and females 16 to 31 mm, averaging 21.0 mm and 22.0 mm, respectively. In a sample taken just south of Nick's Cove, male and female *Acanthina* averaged 22.4 mm and 22.7 mm, respectively. The sex ratio of these samples was 1:1 for *Ocenebra* and *Acanthina*, but three females to two males for *Urosalpinx*. The latter ratio was evidently biased by the sampling technique. Very small drills could not be collected consistently and sexing was difficult, sometimes impossible. For these reasons the computed mean sizes were slightly high.

Two techniques were used for sexing drills. I sexed 400 drills over a period of several months by teasing the shell back on snails attached to aquarium walls and checking for a penis. The second method, used on over 2,000 drills, consisted of cracking the top whorl of the spire in a vice and checking gonad color and consistency. Male gonads generally were smooth, yellow or rich reddish-brown. Female gonads ranged from yellow to orange, but usually appeared granular or even globulated. Some were intermediate, being yellow and smooth, especially in smaller snails; in this case, the rest of the shell was cracked. I regarded absence of a penis as *a priori* evidence of feminine gender as studies show no protandry occurs in *Urosalpinx* or another east coast drill, *Eupleura caudata* (MacKenzie, 1961); and Carriker (1955) found a penis even in very small males.

Drill Activities

Tomales Bay temperatures do not fluctuate as much as those on the Atlantic coast, but there are cycles of activity in both Japanese and eastern drills in Tomales Bay.

A California Department of Fish and Game recording thermograph at Nick's Cove, about 8 miles north of the study area, has provided almost continuous data since 1958. The Department installed another

thermograph at the Tomales Bay Oyster Company in August 1961. Records from these instruments were used in calculating 3-day averages of both high and low water temperatures at approximately zero tidal level.

At Nick's Cove there has been little variation in water temperature ranges the past 4 years. From April through October the temperature ranges above 60° F., with the warmest water during summer. Minima and maxima were 47° F. and 68° F. for Nick's Cove, and 44° F. and 75° F. for Tomales Bay Oyster Company.

Chapman and Banner (1949) studied Japanese drills in Washington State and noted they tended, during winter, to bury in the substrate or crawl into the cracks between or beneath Pacific oyster shells which previously had been used as cultch. The present study partially supports these observations, but *Ocenebra* often was found actively drilling oysters during winter months when few *Urosalpinx* were seen and none was drilling oysters.

These observations differ somewhat from those of Chapman and Banner, but temperature conditions during their study were not given. Although temperature may be over-emphasized by ecologists, it is an important and easily measured parameter and, as such, has been used in defining "physiological races or species" of oysters and oyster drills (Stauber, 1950). Galtsoff (1961) states that experimental evidence is not in harmony with the concept of "critical temperatures," and the response of female oysters is based on their "critical" state of ripeness. Both factors must operate because both *Urosalpinx* and *Ocenebra*, when brought to the laboratory and kept in standing aerated sea water at room temperature (about 68° F.), promptly spawned during December and January.

Copulation by both species was observed in aquaria, although this activity has not been recorded previously (Carriker, 1955). The process is similar to that reported for *Eupleura caudata* (Carriker, 1955; MacKenzie, 1961). Copulation apparently is not necessary immediately preliminary to egg deposition, as female drills may carry viable sperm over a period of 6 months and then deposit fertile egg-cases (MacKenzie, 1961).

Development time within the egg-case varies with temperature (Carriker, 1955). Determining the exact number of days is difficult as drills may spend a week or more depositing their egg-cases. *Urosalpinx*, *Ocenebra*, and *Acanthina* all deposited egg-cases in aquaria, but only *Urosalpinx* developed to the protoconch stage and eventually hatched.

Some differences in activity between *Ocenebra* and *Urosalpinx* may be related to spawning. *Ocenebra* began spawning in late January, reached a peak in February and March, and dropped off in April. *Urosalpinx* spawning started during March, was heavy April and May, and sporadic in late June. South of the oyster beds, *Urosalpinx* spawned in July and August, 1961.

No explanation is available for the observed difference in time of egg-case deposition by *Ocenebra* and *Urosalpinx*. A larger drill control program should be carried out to include this phase of drill biology. The hatching season of *Ocenebra* seems timely for seed oysters which arrive from Japan in mid-April.

To what extent salinity in Tomales Bay affects the distribution or activities of drills has not been determined. *Ocenebra* are found in coastal bays of Miyagi Prefecture, Japan, and *Urosalpinx* are abundant in the waters of Long Island Sound, New York.

Surface salinity samples of Tomales Bay were usually taken during flood tides at Nick's Cove and about a half-hour later at Tomales Bay Oyster Company. Salinities ranged from 21.53 to 36.45 parts-per-thousand at the oyster company, and from 27.16 to 34.53 at Nick's Cove. Wide salinity fluctuations occur after heavy winter and spring rains, but balance is usually restored in a day or two. At the head of the bay, salinity is influenced more by weather conditions than near the mouth, although runoff from Walker Creek, 2 miles from the mouth of Tomales Bay, creates local changes during rainy seasons. Salinity was consistently higher at the Tomales Bay Oyster Company than at Nick's Cove from July into December, while the reverse prevailed the rest of the year.

Because of shallower waters at the head of the bay, both temperature and salinity at Tomales Bay Oyster Company are influenced more by air temperature and runoff than at Nick's Cove, where a rapid exchange with ocean water occurs. Similar conclusions have been made from physical and biological data collected by Pacific Marine Station (Johnson, Bryant, and Hedgpeth, 1961).

In the southwest corner of the oyster beds, 10 clusters of *Ocenebra* egg-cases, from which spawning females were removed, were marked on February 10, 1961. All young conchs had left the cases by April 18. Ten clusters of *Urosalpinx* egg-cases were similarly marked and followed from April 20 to June 26, when most had either hatched or reached late protoconch stages. Egg-cases of *Ocenebra* and *Urosalpinx* were attached to clusters of Pacific oysters or the underside of old oyster shells used to firm areas of soft muddy bottom. Drills outside oyster culture areas generally deposited egg-cases on under surfaces of rocks encrusted with barnacles and native oysters, *Ostrea lurida*.

In the 300-square-foot plot at Tomales Bay Oyster Company, I found an estimated 8,000 *Urosalpinx*, 800 *Acanthina*, and 41 *Ocenebra* egg-cases. A similar sized plot just south of Nick's Cove contained less than 500 *Acanthina* egg-cases. These drills were obtained in late prehatching stages (protoconch) or, in some cases, had already hatched as conchs.

I made no attempt to quantify the number of egg-cases laid by individual drills. Since they tend to spawn in groups on one area, it is difficult to determine the exact number of cases laid by each female. Between 12 and 35 cases were noted for *Ocenebra*; Chapman and Banner (1949) found an average of 25.3. The number of *Urosalpinx* egg-cases falls within the reported variability which is 0-96 per season with an average of 45 (Carriker, 1955).

A sample of 611 *Urosalpinx* egg-cases contained an average of 12.3 embryos each. This was not determined for *Ocenebra* because their cases are opaque and have much heavier outer membranes which are difficult to remove without damaging developing embryos. Chapman and Banner (1949) reported 1,500 eggs in a single case but less than one percent hatched.

Acanthina probably feeds primarily on barnacles and native oysters which may also constitute a large proportion of the diet of *Urosalpinx*, both in and outside oyster beds. Drill damage to cultured oysters was not assessed quantitatively but almost all seed oysters used in chemical barrier experiments were eaten by *Urosalpinx*. There was little damage to the oyster growers' seed, most of which was placed in an area free of drills. *Ocenebra* and *Urosalpinx* moved a short distance from a bed of oysters to seeded areas and drilled some young oysters. During August 1961, one barge-load of 3-year-old oysters suffered more than 25 percent mortality from drills. These oysters were tonged from offshore beds on soft bottom that could not be closely inspected. *Ocenebra* was observed drilling oysters, bay mussels, *Mytilus edulis*, and littleneck clams (*Protothaca staminea*). Young drills often were taken from the under surface of shells encrusted with vermetid gastropods.

Feeding

Chapman and Banner (1949) believed that Japanese drills were not causing excessive damage to Pacific oysters in Willapa Bay, Washington. This conclusion was criticized by Korringa (1952) because damage to small spat was not studied. Chew (1960) found in laboratory studies that Japanese drills preferred Japanese littleneck clams (*Tapes semidecussata*), native oysters, and bay mussels to Pacific oysters. However, neither of these studies has been related to feeding activities when small seed are used as bait. Woelke (1961) found that 10 adult *Ocenebra* consumed 50, 4-month-old oysters in a 20-day laboratory study. McHugh (1957) found that, with fresh bait of seed and adult oysters and oyster shells, the greatest trap catches of *Urosalpinx* were obtained on seed and the least on shells.

Haskin (1950) and Blake (1960) have shown that the metabolism of animals may be important in the activities of their respective predators; those that are actively metabolizing (growing seed) may be more attractive as food. Kohn (1961) has reviewed the evidence for considering the osphradium, a chemoreceptive organ used to seek out particular species and actively metabolizing individuals, while Carriker (1957) has shown that newly-hatched *Urosalpinx* do orient chemotactically to external metabolities of young clams (*Mercenaria*).

Hancock (1954) reported that spat mortalities due to *Urosalpinx* may be as high as 58 percent. The study also shows that drills will not refuse such tender morsels. Thorsen (1958) has made the interesting suggestion that young drills may be much more voracious than adults.

Enemies

Drills have few known diseases, predators, or parasites. Ganaros (1957) has reported a fungus disease in both oysters and in *Urosalpinx* eggs and larvae. Cooley (1957) studied the incidence and life history of a digenetic trematode, *Parorchis acanthus*, in southern oyster drills, *Thais haemostoma*. In samples from Nick's Cove, larval trematodes infested 30 percent of *Acanthina* and 11 percent of *Thais emarginata*.

Chapman and Banner (1959) reported an unknown species of amphipod crustacean living in 23 of 62 *Ocenebra* egg-cases from Oyster Bay,

Washington. No drills or eggs were alive in any cases in which amphipods had constructed mud-tube homes. In *Eupleura caudata* egg-cases from an experimental area, MacKenzie (1961) estimated 19 to 42 percent were damaged. Most damaged cases showed a C-shaped slit or small holes, but occasional cases bore jagged tears. In some of the latter, most of the case had been torn away. Similar jagged tears in egg-cases kept in aquaria were attributed to xanthid mud crabs.

No predators, diseases, or infections of any kind were noted among adult drills in Tomales Bay. In one case, a bat ray, *Myliobatis californicus*, probably by accident, crushed a large *Ocenebra* while feeding on oysters. In the experimental plots, a number of drills, probably distended by chemical treatment, were eaten by scavenging birds.

I observed some damage to drill egg-cases. In a number of clusters laid by *Urosalpinx* and *Ocenebra*, between one-third and one-half of the cases showed jagged tears and in some only the base (peduncle) remained. Usually small crabs were found closely associated with damaged cases, but they were never seen actually feeding on them. In any event, this type of damage must cause considerable reduction to the potential reproductive capacity of drill populations.

DRILL CONTROL

Chemical

The chemicals tested in the Tomales Bay were orthodichlorobenzene (1, 2-dichlorobenzene) and Sevin (1-naphthyl *N*-methyl carbamate) which gave favorable results at the United States Fish and Wildlife Service Biological Laboratory, Milford, Connecticut (Loosanoff, 1960b). These chemicals can be obtained from the Dow Chemical Company and United Carbide Chemical Company respectively. Since 1946, more than 2,000 chemicals have been "screened," and a few found effective on various predators without injuring oysters. Application methods vary according to pest species. For controlling eastern drills, chemicals incorporated with inert carriers such as sand, gravel, or old oyster shells are laid along the perimeter of an oyster culture area. In laboratory tests, chemical barriers 8 to 12 inches wide and 1 inch deep effectively repelled drills for 14 months (Loosanoff, 1956). A barrier of sand and orthodichlorobenzene, 8 inches wide, was effective for 6 months (Loosanoff, 1959).

According to specifications of the Hooker Chemical Corporation (1953) technical grade orthodichlorobenzene has a minimum assay of 85 to 87 percent 1, 2-dichlorobenzene. Its major impurity is paradichlorobenzene. Solubility at 25° C. is 0.013 grams orthodichlorobenzene to 100 grams water, and specific gravity is 1.313 at 15.5° C. It is a clear, colorless liquid possessing a characteristic dichlorobenzene odor.

Barriers incorporating orthodichlorobenzene are enhanced by adding small amounts of Sevin. Sevin of technical grade, made available for experimental studies, has a minimum assay of 95 percent 1-naphthyl *N*-methyl carbamate. It has a solubility of less than 0.01 g/100 g water, and a density of 1.232 at 20° C. Sevin is rapidly hydrolyzed to 1-naphthol in strong alkaline solutions (pH 10). It is a crystalline solid, slightly colored—ranging through pink, lavender, tan, and pale green—and is essentially odorless.

Sand and gravel, available on nearby beaches, were used as the inert components and constituted major proportions of the chemical barriers.

The constituents for experiments in 1961 were mixed in a cement mixer just prior to spreading and transported to the site in double-lined cement bags. The 1962 experimental barrier, using gravel, was mixed by shoveling, carried to the site, and laid on plastic sheeting around an area previously planted with oyster seed. The 1962 experiment, using sand, was handled as in 1961.

Spreading these mixtures was a major effort because it was done by hand during low tides, and often very soft mud had to be traversed to reach an experimental plot. To test the chemicals' effeciency, five plots were used in 1961 and three more during 1962.

In evaluating the 1961 chemical barrier treatments, two plots were planted with Pacific oyster seed (length, one-quarter to one-half inch) and left for several weeks without further treatment. The remaining plots were planted with 1- and 2-year-old Pacific oysters (3-7 inches), and the area around the barrier planted with marked drills, both *Ocenebra* and *Urosalpinx*. Live drills were marked with a hand drill using a saw-tooth burr. In 1962, the barrier evaluation was made in much the same manner, utilizing drills obtained from trap studies to follow subsequent movements and mortalities when placed outside the "barrier-protected" plot. The two plots, completely covered with chemically treated sand, were surveyed after several weeks and surviving drills and "recent" shell materials were counted.

Trapping

Trays with one-quarter inch wire mesh bottoms were used to test the efficiency of drill trapping. Each tray was 3 feet square, 4 inches deep, and divided into four equal compartments.

Each tray was baited with various combinations of oysters, barnacles, mussels, and clams, and then placed on a selected oyster bed which had been harvested about 8 months previously. Ten trays were strung at 10-foot intervals on a single line. The trap-line was surveyed and moved periodically from March through June 1962, when drills were actively feeding. During each check, the number of drills found on each bait species was noted to provide quantitative data on feeding behavior.

1961 EXPERIMENTS

The first barrier, laid on February 25, 1961, consisted of beach gravel with 4.7 percent orthodichlorobenzene and 0.3 percent Sevin, by volume. I found that 30 percent fine sand was needed in place of an equal amount of gravel, since the latter did not bind the orthodichlorobenzene in a workable dry-mix. This barrier surrounded a 16- x 12-foot plot, high in the intertidal zone on firm rocky ground about 50 yards south of Tomales Bay Oyster Company's dock.

Fifty *Ocenebra* and 165 *Urosalpinx*, marked on the first whorl, were placed on 33 clusters of 1- and 2-year-old oysters (length, 3-7 inches) in the plot. Groups of five *Ocenebra* (total 100) and 10 *Urosalpinx* (total 200) were marked on the second whorl and placed at intervals around the outside edges of the barrier.

For the next several days and periodically for several months, checks were made during low tides. The barriers, originally 12 inches wide and 1 inch deep, widened to over 36 inches on lower (bayward) and upper (shoreward) ridges within 2 days. Leaching of the chemical was indicated by larger numbers of dead or dying amphipods (probably *Corophium*), patelloid gastropods (*Acmaea*), and polychaetes littering the ground for 30 feet southeast (prevailing winds from northwest) and 15 feet bayward from the plot. Thousands of burrowing amphipods lay in depressions filled with water; others had been trapped on the mud. Those alive were swimming on their sides in erratic circles. Several polychaetes were noted in the mud, half out of burrows. Those close to the barrier were dead, but distant ones reacted very slowly when probed. Limpets had feet distended to mushroom-like shapes, and some had fallen off rocks into water-filled depressions; others remained attached, although they could not retract and were very easily removed. Some drills were swollen so that retraction into their shells was impossible while others were so tightly closed their opercula could barely be seen. Both *Ocenebra* and *Urosalpinx* were affected.

No ill effects were observed for anemones, *Anthopleura elegantissima*, or oysters, some of which were placed on the barrier. Later, during spring and summer, surviving Japanese and eastern drills both were observed depositing egg-cases in the test plot.

Heavy mortality of drills and limpets was evidenced by broken or empty shells in the area on the second and third days. This mortality probably can be attributed to gulls or shorebirds, whose tracks were on the barrier. They had probably fed on drills and limpets immobilized by the chemicals. Scavengers, such as isopods and crabs, may also prey on immobilized animals, but more likely, they also are repelled or killed by the chemicals. Collections of drills and limpets on the third day, and after 2 weeks of barrier "life," showed that distended animals would recover if removed from around the barrier and released in untreated sea water. Worms and crustaceans had disappeared by the third day.

On March 12, 110 marked *Urosalpinx* were placed outside the barrier in positions marked with small dowels and their movements followed for 3 successive days. Some were immobilized and those attached to small rocks did not move, others moved randomly up to 44 inches during the 3 days. On the 19th day, three were observed crossing the barrier which at this time was between 18 and 45 inches wide.

The barrier was not effective after 1 month, though odor of dichlorobenzene remained. Drills placed on it displayed normal activities for 2 days. After 3 months, the gravel and sand barrier had been washed out completely by wave action.

On April 17, and again on April 20, Japanese seed oysters (length, $\frac{1}{4}$ to $\frac{1}{2}$ inch) on fragments of cultch shell were laid in each of two, 10-foot-square areas. One plot was about 50 yards north and the other about 50 yards south of the oyster company dock and lower in the intertidal zone than in February. Both plots were protected with barriers 8 inches wide and 1 inch deep. The mixture used was the same strength (5 percent total chemicals, by volume) as the February experiment, but Dillon Beach sand was used in lieu of gravel. Both new plots were chosen because the ground was fairly firm and free of drills, shells,

rocks, and other litter. A severe storm 2 weeks after the experiment was started, buried some oysters with silt and spread out much of the barrier. The seed, left unattended until June 29, 1961, was removed and mortality due to drills recorded. All seed from the plot south of the dock was drilled, while over 80 percent from the northern plot was drilled. The barrier's effectiveness had been removed by the storm.

On June 26, six clusters of 2-year-old oysters (length, 6-8 inches) were placed in each of two plots 4 feet square surrounded by 8-inch barriers of sand and chemicals. In one plot 40 *Urosalpinx* and 10 *Ocenebra* were placed; the other was surrounded with 40 *Urosalpinx* and 10 *Ocenebra*. The plots were checked daily for 3 days. Wave action spread the treated sand over both plots and effectively buried most drills which had not climbed upon oysters. Some drills on oysters were swollen, but those which remained attached had recovered by the third day, while drills buried by the treated sand died. The effects of the treatment on other animals in the area were similar, but more limited than those observed during the first experiment. These barriers were completely washed away in 7 days.

1962 EXPERIMENTS

On April 2, 100 pounds of sand and 2,000 pounds of gravel ($\frac{3}{4}$ inch or less in diameter) were mixed with 100 pounds of orthodichlorobenezene and 1 pound of Sevin. A plot 22 x 44 feet was surrounded with a strip of the mixture 8 to 18 inches wide and 1 to 5 inches high on agricultural plastic sheeting 18 inches wide. The total cost of this treatment, excluding 15 man-hours labor, was about $50.

Immediately observable effects were (i) drying of the barrier surface, (ii) draining of some chemical from the barrier onto surrounding flats and into depressions, (iii) dispersal of some chemical as an oily surface film on the water as the tide returned.

On the following day when the area was checked during low tide, groups of amphipods and various other crustaceans were found dead in pools; organisms were dying 100 yards south of the barrier, and swollen but attached patelloid gastropods were found 40 to 60 yards south of the barrier, indicating that some chemical had been carried in solution or as surface film by wind and tide. In this same area *Urosalpinx* were not visibly affected. By the third day the area appeared normal, except for a few pockets containing dead amphipods, and three dead shore crabs near the plot. No effects were noted on drills attached to oysters outside the plot or on bare mud. One native drill in contact with the barrier was swollen and distended from its shell.

On April 23 and 24 and May 6 and 7, 285 *Urosalpinx* and 40 *Ocenebra* were collected and planted in the area and their activities noted for several weeks. It was impossible to find all these drills during any one day of observation, but some individuals were followed for several days. During the first few days most did not attempt to cross the barrier, though some moved upon larger rocks. These drills were usually not retracted or swollen, but reacted slowly when probed.

By the end of the first month, drills had crossed the barrier and entered the plot. The barrier had become spread and flattened but, in general, was still intact. By April 28, the gravel had washed off the

plastic sheet at two places along the lower edge, and by May 7 the barrier was heavily silted in some areas. A few drills were still affected and a few moribund crabs were found. Digging into the barrier revealed chemical retention, but drills could cross over silted areas with little difficulty. Forty *Urosalpinx* placed outside the barrier on May 20 had no difficulty crossing.

The second series of experiments was started May 7. Two, 10- x 10-foot areas were staked out in extensive beds of old oyster shells. One plot was at about zero tidal level while the other was at plus 1 foot. The latter had been enriched with 57 *Ocenebra* and 17 *Urosalpinx* on March 3, 1962.

Each plot was covered with 50 pounds of chemically-treated sand (0.1 part Sevin: 10 parts orthodichlorobenzene: 100 parts sand) and left undisturbed until May 23 when the plot at zero tide level contained 172 live and 22 dead *Urosalpinx* and 20 live and 9 dead *Ocenebra*. In the plot at plus 1 foot tide level the mortality was greater. There were 85 live *Urosalpinx* and 29 dead; 14 *Ocenebra* were found alive and 26 dead.

DISCUSSION

Chemical

Extreme caution should be exercised when applying pesticides to marine environments. During the many years of laboratory testing of chemicals, including proven insecticides, researchers have found some are extremely toxic to beneficial or commercially valuable species. The balance between these and pest species must be carefully considered before control measures are attempted. The ideal chemical for oyster drill control would be species-specific, probably having a combination of high specific gravity and extremely low solubility to minimize pollution.

Although orthodichlorobenzene adversely affects crabs, starfish, drills, and other oyster predators or competitors, Loosanoff (1956) found that sessile animals settling a fraction of an inch away from test barriers carried on apparently normal existence. "It is, however, highly improbable that the concentration created, even in the immediate vicinity of the barrier, exceeds 0.001 ppm," (Loosanoff, 1956). He also reported that orthodichlorobenzene is not particularly injurious to cattle; a dosage of 110 mg per pound body-weight fed to a calf for 13 days caused no ill effects. Loosanoff in his review of other literature reported that in food, a dosage of 1,333 ppm was not injurious to cattle or sheep.

Loosanoff also stated that orthodichlorobenezene caused swelling of the epidermis and affected gastropods could not withdraw into their shells. Being an organic solvent, it may affect mucus solubility and thereby penetrate the slimy sole of the snail.

Much assay work has been done showing that Sevin is effective against a wide variety of insects, crustaceans, and mollusks (Loosanoff, 1960a; Ruppel, 1959). The studies of Haynes *et al* (1958) show that it is relatively nontoxic to mammals, birds, and fish.

The chronic toxicity of Sevin is low, as is shown by a number of feeding experiments. There was no effect on dogs fed 400 ppm in dry

diets 5 days per week for 1 year, or on rats fed a dosage of 200 ppm for 2 years. Hen chickens showed no ill effects after receiving 3,000 ppm dosages for 8 days. The toxicity to fish varies widely with species. Tests with bluegill, goldfish, trout, and salmon show that most species are 200 times less susceptible to Sevin than to similar treatment with DDT. Carriker and Blake (1959) found that Sevin caused relaxation of the foot of *Urosalpinx* and was a useful narcotizing agent when used in conjunction with CO_2 and dry-ice.

Ruppel (1959) found that, against the grey garden slug, *Deroceras reticulatum*, of Colombia, sprays of 0.3 percent Sevin (50 percent wettable powder) were ineffective, but baits of 2.5 percent and 1.25 percent Sevin resulted in high mortalities: 96 hours (100 percent) and 120 hours (76 percent), respectively. Haynes *et al* (1958) found that the wettable powder formulation appeared to be twice as toxic to goldfish as technical Sevin. They suggested that increased toxicity may have been a function of solubility of the insecticide, since no mortality was experienced in the control containing only the inert constituents of the powder.

Although drills are made torpid or repelled by chemical barriers containing orthodichlorobenzene and Sevin, there is no conclusive proof that the chemicals are a direct cause of drill mortalities. Tests have shown that swollen gastropods usually recover if transferred to fresh sea water and, in plot studies, drills which remained attached to shells protruding above the substrate were not affected. Davis *et al* (1961) found, in large-scale field tests, that starfish took a large toll on affected gastropods, and that subsequent drill trap catches were significantly lower in treated than untreated areas. Potential drill predators such as crabs and other crustaceans are affected by the chemicals used in this study.

A comparison of hydrographic characteristics of Tomales Bay and Long Island Sound (Riley *et al*, 1956) show basic differences that make application of similar drill control methods different problems. Especially pertinent to the drill barrier studies conducted at Tomales Bay, are the combined effects of wind, waves, tides, and sedimentation on intertidal oyster beds. All are highly variable and because of the intermittent nature of my study, could be estimated only from aftereffects.

The effective life of the sand-chemical mixture used is less than 1 month during winter and spring, and only slightly longer, subject to high wind and low tide combinations, during summer. Siltation destroys the barrier's effectiveness without physically disrupting it.

Benefits from control measures can be increased manyfold by reducing effectiveness of reproductive phases of drills and protecting oysters during their first year of growth. Whole oyster shells used as fill, to firm soft mud, provide substrate for the greatest percentage of drill egg-cases. Further work should be done using chemicals in these areas, and oyster growers should be encouraged to crush the shell prior to spreading it over mud.

This study has not invalidated the principle of using chemicals for drill control, but points out the need for further study on methods of application.

Trapping

Traps which have been used successfully in the United States described by Galtsoff *et al* (1937), Carriker (1955), and Federighi (1931), have been ineffective in Europe and Canada (Adams, 1947). The density of drills in traps was not significantly higher than on the surrounding bottom.

I felt that traps used in this study were less than 50 percent effective. The most drills were caught in traps on highly infested shell piles. Traps on soft mud caught the least. Traps on mud, baited with barnacles, accounted for more drills than those with bivalves as bait. Cockles, clams, and large oyster seed were rather ineffective baits. Traps were ineffective for large-scale trapping, though if used in shell piles, many drills were caught.

During my trapping experiment, I noted that barnacles present on seed were consumed by *Urosalpinx* before attacks were made on the seed itself. Similar protection of oyster spat afforded by attached mussels (*Mytilus recurvus*) was reported by Nelson (1923). He records that *Urosalpinx* attacked the thinnest-selled mollusks first, and abandoned oysters with thick shells in favor of thin-shelled mussels. Conversely, some have found that whelks (*Thais*) had difficulty in changing their food from mussels to barnacles. Connell (1961) found that *Thais lapillus* was selectively feeding on the oldest and largest barnacles. Possibly drills can be diverted by planting seed fouled with barnacles. Later attacks on larger seed would be less destructive because of longer time required for drilling and feeding, or by a change in drill behavior, such as from feeding to spawning.

SUMMARY

Mixtures of orthodichlorobenzene and Sevin incorporated with inert carriers of dried sand and gravel were used on experiments to protect oyster plots from invasion by drilling gastropods, *Urosalpinx cinerea* and *Ocenebra japonica*.

Because of physical problems caused by wind and water on intertidal oyster beds, barriers were not effective in repelling drills for periods of more than 1 month. Gravel was less affected by water action than sand, but did not bind liquid orthodichlorobenzene in a workable, dry mix. Siltation was the major factor limiting effectiveness of gravel barriers.

Trapping studies indicated the traps used were rather inefficient for controlling drills on intertidal oyster beds in Tomales Bay. Specially designed traps can be used in areas spread with oyster shells to firm soft mud bottom. Such areas are prime habitat for *Urosalpinx* and *Ocenebra*. Trap catches showed *Urosalpinx* may prefer barnacles to oyster seed as food, indicating the possibility of biological controls, such as barnacle-covered rocks or oyster shells to divert drill activity while the oysters attain a less vulnerable size.

Preliminary studies were made on the ecology of Tomales Bay. The distribution of *Ocenebra* and *Urosalpinx* is limited to the eastern shore south of Marshall. *Ocenebra* is not found outside the fenced area of Tomales Bay Oyster Company, but *Urosalpinx* has spread both north and south. *Acanthina spirata* is found throughout the bay, except south of Millerton, where *Urosalpinx* abounds.

Data are presented on the relative numbers of drills and their egg-cases. In 1961, *Ocenebra* spawning peaked in February and March, while *Urosalpinx* peaked in April and May at the oyster beds. *Urosalpinx* is considered the greatest menace because of a much larger population, but *Ocenebra*, which reaches a larger size and remains active most of the year, should not go unchecked.

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UNDERWATER TAGGING GUN [1]

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With the advent of SCUBA, more and more biologists started venturing into the sea to study plants and animals in their natural environment. Concurrently, a need developed for new techniques of observing, recording, and collecting organisms while using this gear. One of our contributions is the underwater tagging gun (Figure 1) described here.

I designed this gun to help Department biologist-divers understand and interpret fluctuations of fish populations around artificial reefs in Santa Monica Bay. The apparatus is remarkably effective for tagging sedentary fishes, such as rockfishes (family Scorpaenidae), and flatfishes (families Bothidae and Pleuronectidae). Kelp bass (*Paralabrax clathratus*), sand bass (*P. nebulifer*), ocean whitefish (*Caulolatilus princeps*) and several species of surfperches (family Embiotocidae) also have been tagged successfully with the gun. With slight modifications, it could be used to tag many other species. In some preliminary tests, sculpins (*Scorpaena guttata*) seemed almost unaware they had been tagged, showing little reaction to the tag penetrating their flesh. We applied yellow FT-2 dart tags previously used experimentally on tuna (Blunt and Messersmith, 1960) and found them quite visible underwater at depths of 60 to 100 feet.

CONSTRUCTION

The gun, constructed of plastics, stainless steel and brass, cost approximately $10. Its barrel is 1-inch tubular plastic, 23 inches long. The carriage, supporting the handle and trigger mechanism, was fabricated from $^{3}/_{16}$-inch plastic sheet stock. The stainless steel shaft or tagging needle holds the tag and is beveled at a 25-degree angle on one end to insure a smooth fit for the tag's dart head. The other end is crimped into a plastic disk where the cocking handles also attach. The shaft is propelled by a 10-inch compression spring, $\frac{5}{8}$ inch in diameter. Spring tension can be varied by inserting plugs between the spring and back plate, thereby adjusting the thrust to any desired amount. A 5-pound thrust was satisfactory for tagging sculpins. When the gun is fired, the tagging needle is checked at the forward end of the 10-inch-long travel slots by a plate and a compression spring.

The cocking handles, protruding from the side slots, make it easy for the diver to cock the mechanism even with gloved hands.

In underwater tagging operations we employ two divers. One carries only the tagging gun, the other carries a clipboard with plastic writing sheet for recording species, tag numbers, and estimated fish lengths.

[1] Submitted for publication June 1963. This work was performed as part of Dingell-Johnson Project California F-17-R "Ocean Fish Habitat Development," supported by Federal Aid to Fish Restoration Funds.

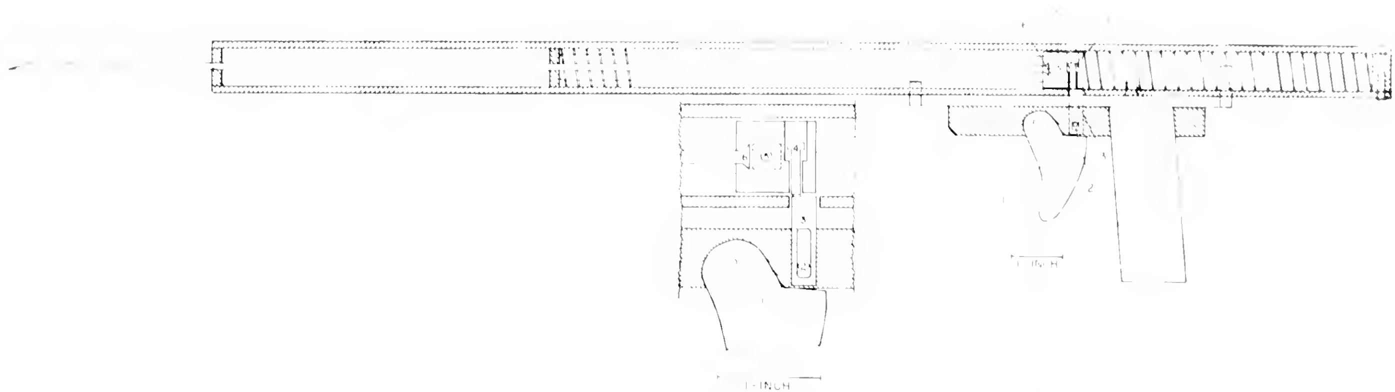

FIGURE 1. Cut-away diagram of the underwater tagging gun with an enlarged schematic of the trigger and related components. 1. trigger, 2. sear pin, 3. sear, 4. firing pin, 5. cocking handle, 6. crimped end of tagging needle.

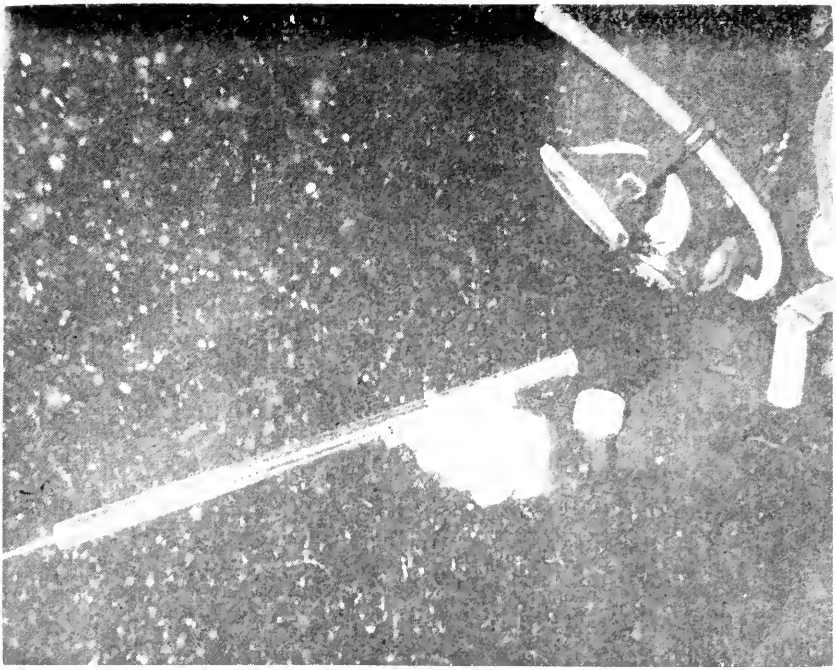

FIGURE 2. The author with the tagging gun underwater. *Photograph by Charles H. Turner.*

FIGURE 3. Gun and fish *(Scorpaena guttata)* in proper position for tagging. *Photograph by Charles H. Turner.*

FIGURE 4. Retracted gun and marked fish. *Photograph by Charles H. Turner.*

A tag holder, made from a 2- by 18-inch strip of $\frac{1}{4}$-inch neoprene rubber, is attached to the clipboard. Tags are inserted through the rubber at $\frac{1}{2}$-inch intervals in two rows running the length of the rubber strip. We carry up to 64 tags and have marked as many as 30 fish in 1 hour at a depth of 60 feet.

Tags are inserted in the forward end of the needle before cocking the gun. Fish are approached from the rear and slighly above to within 10 inches. The gun drives the tag into the back muscles 1 to $1\frac{1}{2}$ inches.

There are certain limitations and definite advantages to tagging fish underwater. Advantages are:

1) Fish can be tagged with little noticeable shock, and their condition can be observed after tagging.
2) Fish are tagged in their natural environment, thus reducing their susceptibility to predation immediately after tagging.
3) Fish are not handled.
4) Fish with swim bladders do not suffer from bladder expansion as do those brought to the surface.

Limitations include these:

1) The tagging range is restricted (less than 10 inches), so fish must be amenable to close stalking.
2) Fish lengths can be estimated only, so accurate growth data cannot be obtained.
3) A diver's working time at depths below 100 feet is limited. Currently, we are studying several modifications of this basic model including a larger gun and using compressed air to extend the tagging range.

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SOME EFFECTS OF SEWER EFFLUENT ON MARINE LIFE[1]

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INTRODUCTION

In March 1956, the Department of Fish and Game initiated a series of trawling ventures to collect California halibut, *Paralichthys californicus*, for tagging and life history studies. During this work, occasional morbid fishes of several kinds were taken in the nets. Additional abnormal fishes were brought to the California State Fisheries Laboratory by other investigations and individuals. Skindivers complained that abalones from the White Point area were flaccid and their meat contracted within the shell.

On-the-spot examination of some of the affected animals led us to believe pollution was the only logical cause of the injuries. Clinical, experimental, and literary support for the pollution theory was obtained and the data presented here describe some of the abnormalities observed on marine animals taken within, or adjacent to, known polluted areas along the southern California coast. The exact process and specific agents causing mortality and morbidity are seldom detected. That pollution can and does destroy aquatic life both insidiously and dramatically has been documented frequently.

The Los Angeles City Hyperion sewer outfall in Santa Monica Bay, Los Angeles County outfall at White Point, and the effluent from numerous discharge points within the Los Angeles-Long Beach Harbor are the chief sources of pollutants in the metropolitan area. Although more than a half billion gallons of wastes from Hyperion and White Point are delivered to the open sea each day, there is a fair degree of dilution in a limited space. The harbor, however, confines a large portion of the wastes deposited within its borders. Reish (1955) demonstrated that serious damage had already occurred to bottom life at a number of places in the inner harbor and at least one area in the outer harbor.

DAMAGE TO CALIFORNIA HALIBUT

Thousands of California halibut caught by trawl gear in the Long Beach Harbor, 1956-1958, were abnormally listless, dull-colored, and soft to the touch. Halibut caught outside of the harbor during the same period were vigorous, brightly spotted, and firm-fleshed.

In the spring of 1957, several dead halibut were caught in the nets in a heavily polluted area near Long Beach. These were inspected for bites, hook injury, or other tissue damage and gross indications of

[1] Submitted for publication July 1963.

disease. None was evident and it was assumed some toxic substance in the effluent, probably originating in the nearby Los Angeles River, caused death. No dead halibut were ever trawled in any other area.

WEIGHT LOSS IN SPOTTED TURBOT

Numerous spotted turbots, *Pleuronichthys ritteri*, were captured with trawling gear in a heavily polluted area at Long Beach. Others were taken in the relatively clean Surfside-Sunset Beach area outside of the harbor. Those from Long Beach were thin and in very poor condition. Length-weight data were taken from turbots in both areas and subjected to statistical analysis.

The weight-length curves were transformed to straight lines by taking logarithms of the weights and lengths. The statistics of the regression lines are shown in Table 1. Tests were first made on the

TABLE 1
Statistics of the Log Weight-Log Length Regression Lines for Spotted Turbots, 1957

Group	N	$\bar{x}$	$\bar{y}$	*a*	*b*
Surfside-Sunset, Jan. 28-Feb. 6	44	2.25795	2.22363	—5.65720	3.49587
Surfside-Sunset, Apr. 30-May 10	96	2.25259	2.20051	—5.95810	3.62188
Surfside-Sunset, pooled dates	140	2.25428	2.20778	—5.88908	3.59179
Long Beach, Jan. 28-Feb. 6	120	2.26640	2.25737	—4.20016	2.87572
Long Beach, Apr. 30-May 10	60	2.26860	2.24714	—3.69487	2.61924
Long Beach, pooled dates	180	2.26714	2.25397	—4.05011	2.78064

TABLE 2
Analysis of Log Weight-Log Length Regression Lines for Spotted Turbots Caught in the Surfside-Sunset Beach Area During Two Time Periods, 1957. Test is for Differences in Slope and/or Level

Source of variation	*Degrees of freedom*	*Sum of squares*	*Mean square*
Between time periods	2	0.01038	0.00519
Within time periods	136	0.54978	0.00404
TOTAL	138	0.56016	

$F_{2,\,136} = 1.28$

TABLE 3
Analysis of Log Weight-Log Length Regression Lines for Spotted Turbots Caught in the Long Beach Harbor Area During Two Time Periods, 1957. Test is for Differences in Slope and/or Level

Source of variation	*Degrees of freedom*	*Sum of squares*	*Mean square*
Between time periods	2	0.01308	0.00654
Within time periods	176	0.82062	0.00466
TOTAL	178	0.83370	

$F_{2,\,176} = 1.40$

TABLE 4
Analysis of Log Weight-Log Length Regression Lines for Spotted Turbots Caught During Pooled Time Periods in the Surfside-Sunset Beach and Long Beach Harbor Areas, 1957. Test is for Differences in Slope and/or Level

Source of variation	*Degrees of freedom*	*Sum of squares*	*Mean square*
Between areas	2	0.07114	0.03557
Within areas	316	1.38364	0.00438
TOTAL	318	1.45478	

$F_{2,\,316} = 8.12$

TABLE 5

Analysis of Log Weight-Log Length Regression Lines for Spotted Turbots Caught During Pooled Time Periods in the Surfside-Sunset Beach and Long Beach Harbor Areas, 1957. Test is for Difference in Slope

Source of variation	*Degrees of freedom*	*Sum of squares*	*Mean square*
Due to common slope (between areas)	1	0.07004	0.07004
Within areas	316	1.38364	0.00438
Deviations from regression lines with a common slope	317	1.45368	

$F_{1,\ 316} = 15.99$

weight-length regression lines from different time periods for the same areas. No significant differences were found (Tables 2 and 3). Consequently, samples for the two time periods within each area were pooled. Regression analysis showed a significant difference between the pooled weight-length lines for the two areas (Table 4), and further showed that there was a significant difference between their slopes (Table 5). The transformed weight-length line for the Surfside-Sunset Beach specimens exhibits a greater slope than does the line for the Long Beach spotted turbots, demonstrating that turbots living in clean water were heavier for their length than those living within the highly polluted harbor.

EXOPTHALMIA IN SPOTFIN CROAKER

Spotfin croakers, *Roncador stearnsii*, taken off Long Beach in 1956 and 1957 were suffering from exopthalmia (abnormal protrusion of the eyeball) while those from clean water were normal. Findlay E. Russell, M. D. (pers. comm.) examined the damaged eyes and concluded that

FIGURE 1. Exopthalmia as found on white seabass. *Department of Fish and Game photo.*

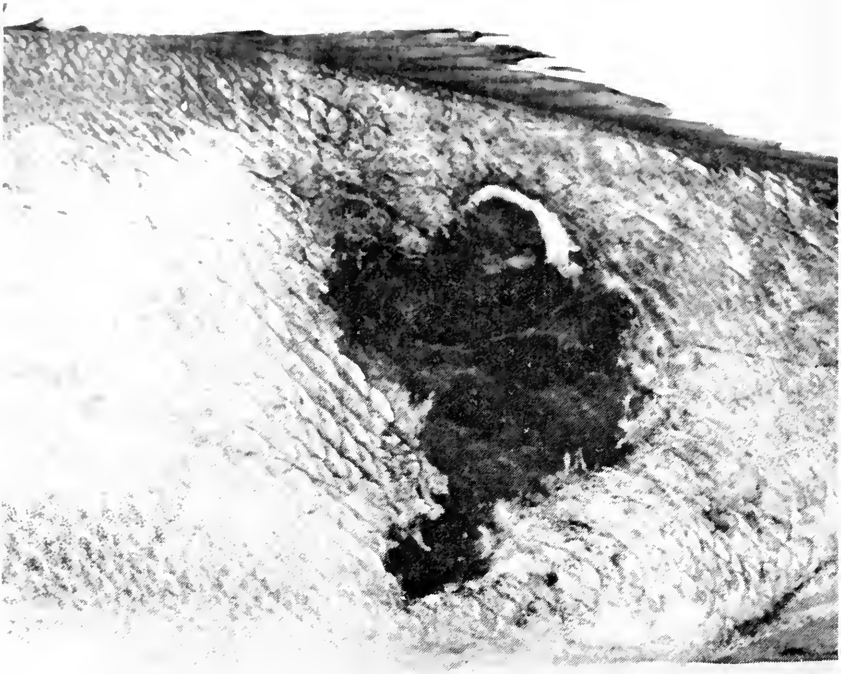

FIGURE 2. A large lesion appearing on the body of a white seabass. *Photograph by Jack W. Schott.*

toxins, as a result of infection were probably causing the trouble. Specific mention was made that toxic substances present in the water could be absorbed into the fish and thus produce this condition. Similarly affected spotfin croakers have been taken in Santa Monica Bay, another highly polluted body of water. The condition has never been noted among spotfin taken in clean waters.

EXOPTHALMIA AND LESIONS IN WHITE SEABASS

White seabass, *Cynoscion nobilis,* taken within the outer harbor in early 1957, and thereafter, were also suffering from exopthalmia (Figure 1). Others have had large lesions on the sides, head, snout, and tail (Figure 2). Lesions of the skin, similar to those on white seabass, were produced experimentally on killifish, *Fundulus parvipinnis,* (John Prescott, pers. comm.). He took samples of combined effluent issuing from Dominguez Channel (inner harbor) during low tide and diluted them with sea water to 3 to 10 percent. Killifish introduced into the dilute mixture generated whitish lesions on the body in a 12-day period, and death resulted even after they were removed and placed in clean water.

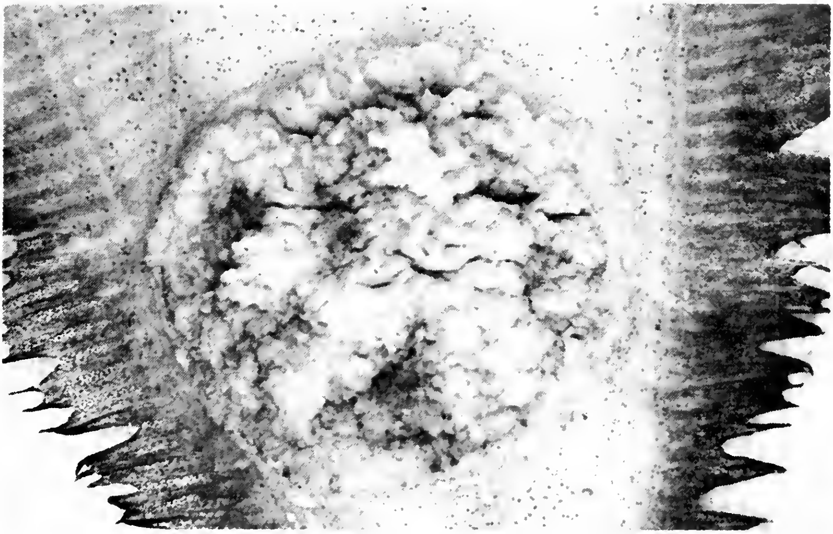

FIGURE 3. An example of the lesions found on small Dover sole. This one is on the underside of the body. *Photograph by Jack W. Schott.*

Exopthalmia is not fatal of itself, but results in loss of the eye, probably by rupture. Small white seabass, up to approximately 30 inches, suffer exopthalmia, but there are no records of large adult fish exhibiting the injury. Presumably, small fish, by losing their eyesight, do not reach large size.

LESIONS ON DOVER SOLE

Many 4-6 inch Dover sole, *Microstomus pacificus*, trawled in Santa Monica Bay carried one or more "cancerous" lesions on the body (Figure 3). Larger Dovers, ranging upwards from 10 inches, did not show lesions or scarring. Evidently, only immature fish suffer these lesions which apparently eventually cause death.

LIP PAPILLOMA IN WHITE CROAKERS AND OTHER SPECIES

During May and June, 1956, 353 white croakers, *Genyonemus lineatus*, were caught with trawling gear in Santa Monica Bay. Ten taken within 2 miles of Hyperion sewer outfall had tumor-like sores about the mouth (Figure 4). Histologic examination of these tumors (Russell and Kotin, 1957) revealed the sores were not malignant, but probably caused by mechanical, infectious, or chemical irritation. Russell and Kotin referred to a paper by Lucke and Schlumberger (1941) where it was noted similarly affected catfish were taken from the heavily polluted Schuylkill and Delaware Rivers. Since 1956, numerous papillomic white croakers have been taken in both Santa Monica Bay and the Los Angeles-Long Beach harbor area. Papillomas have been observed on tongue soles, *Symphurus atricauda;* basketweave cusk-eels, *Otophidium scrippsae;* and Pacific sanddabs, *Citharichthys sordidus,* from these two areas. Such tumors have never been observed on fish from unpolluted areas.

FIGURE 4. Tumor-like growth on the mouth of a white croaker. *Photograph by Jack W. Schott.*

WEIGHT LOSS AND MORTALITY OF BLACK ABALONES

Black abalones, *Haliotis cracherodii*, taken at White Point, April 1956, were significantly lighter in weight than those taken at Santa Catalina Island in the same month. As length increased, weight differences increased (Figure 5).

To test the effect of environment, 157 White Point black abalones were tagged and released at Catalina Harbor, and 335 Santa Catalina Island abalones were released at White Point during the period April 5-9, 1956. In two months, weight increased significantly for the abalones transplanted to Santa Catalina Island, whereas those moved to White Point failed to show much change (Figure 6). The compara-

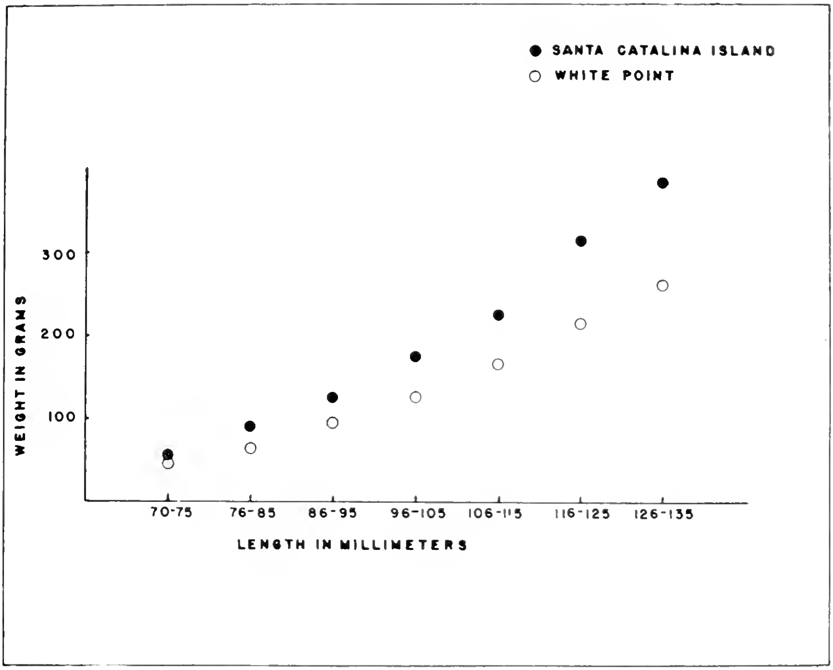

FIGURE 5. Mean weight of black abalones collected at White Point and Santa Catalina Island, April 1956.

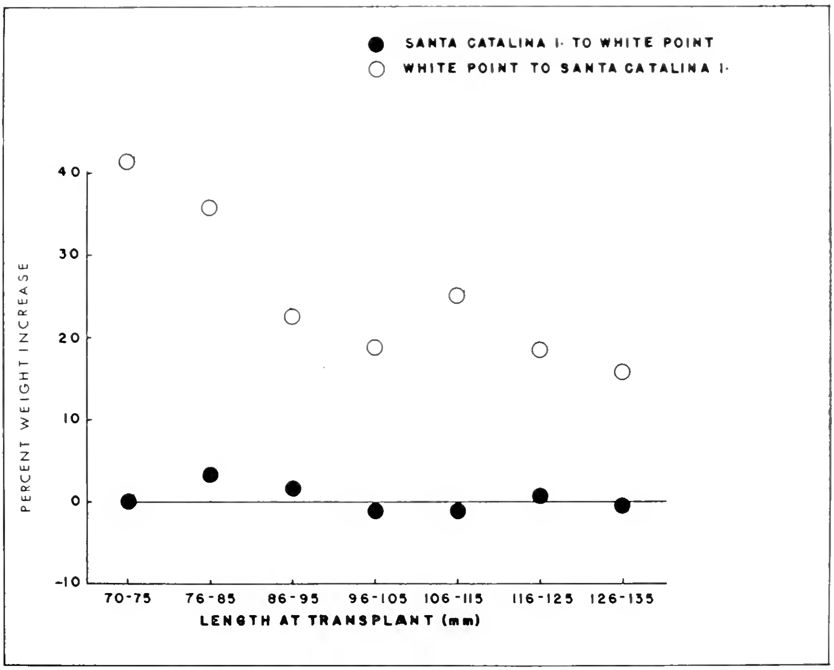

FIGURE 6. Mean weight change of black abalones transplanted from Santa Catalina Island to White Point, and White Point to Santa Catalina Island, April 5-9, to June 12-13, 1956.

tively remarkable weight increase of the abalones transplanted to Santa Catalina I. shows they were starving at their White Point home. Even though the group transplanted to Santa Catalina I. profited extensively as a whole, 11 empty shells were found within several months. The live weights of nine were well below the mean weight of their corresponding size group. These abalones were either starved to a point beyond recovery, or unduly injured by the tagging and transplanting process. Insurmountable weakness induced by starvation appears most logical.

Since the transplantation experiment, large (old) black abalones have been almost non-existent at White Point. Most there are less than 3 inches long.

Along with starvation, White Point black abalones endured a succession of caustic baths that seriously eroded the outer shell. There may also have been a number of fatalities, but it is not possible to document this.

DISCUSSION

California halibut are attracted to the Los Angeles-Long Beach harbor area, particularly Long Beach. The nearest source of effluent, the Los Angeles River, is 3 miles west of the most productive halibut grounds. Water quality objectives were adopted for Los Angeles River and tidal prism in June 1954. However, "bootleg" dumping was and is a problem in the Los Angeles River storm drain system. Normal effluent may be attractive to halibut for the small bait fishes that are found there, but toxic flows have been occurring for years. The condition of halibut in the Long Beach area, 1956-1960, indicated the habitat was not of optimum quality. Finding dead halibut in the nets in 1957 was the only time and place this happened in more than 4 years of fishing between Santa Barbara and central Baja California.

Spotted turbot caught along with halibut at Long Beach proved to be lighter for their length than those from outside the harbor. Although harbor waters may have had a direct effect upon turbot, they almost certainly affected the bottom life, primarily worms, these turbot feed upon. In this respect, halibut differ as their diet is chiefly fish.

Spotfin croaker and white seabass, taken at Long Beach and in Santa Monica Bay, had developed exophalmic eyes.

The lesions found on white seabass and killifish, and the tumors found on white croaker and catfish appear to be associated with pollution. The Delaware and Schuylkill Rivers have a long history of extreme pollution, showing a significant relationship between water quality and tumors on catfish. It is more difficult to show direct relationship in marine waters. Nevertheless, lesions, like those on white seabass, were produced experimentally on killifish under controlled conditions of pollution.

Black abalones feed on plant material, fixed and floating. White Point black abalones were unable to find enough plant material to fill their needs whatever the source. White Point effluent, directly or indirectly, destroyed the plant life upon which abalones depended. Some of the abalones transplanted from White Point to Santa Catalina Island died despite an abundance of food and clean water. From this, we must assume the death rate of White Point abalones is abnormally high.

SUMMARY

In early 1956, a long series of bottom trawling was started as part of a study centered around California halibut. Abnormal halibut and other species of fish were trawled from time to time in specific areas. Ultimately, all factors other than pollution were eliminated as the agents causing abnormality. From 1956 to the present time, 1963, trauma among marine animals has been observed repeatedly or induced experimentally in polluted environments. Examples of injuries are as follows:

1) Thousands of California halibut caught near Long Beach, 1956-1960, were dull-colored, listless and soft to the touch; several were dead.

2) Spotted turbots from the same area were not as heavy for a given length as turbots from outside the harbor.

3) Spotfin croakers and white seabass from Long Beach and Santa Monica Bay suffered exopthalmia.

4) White seabass also exhibited large lesions about the body.

5) White croaker and other species taken near Hyperion outfall in Santa Monica Bay and in Long Beach Harbor had tumor-like sores about the mouth, probably caused by mechanical, infectious or chemical irritation.

6) Lesions similar to those on white seabass were produced experimentally on killifish by exposing to a three to seven percent solution of Dominguez Channel effluent for 12 days.

7) The weight-length curve of black abalones from White Point was significantly lower than the curve of Santa Catalina Island black abalones. White Point abalones transplanted to Santa Catalina Island gained up to 42 percent weight in 2 months, while Santa Catalina abalones transplanted to White Point failed to gain and eventually died.

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NOTES ON THE LIFE HISTORY AND A DESCRIPTION OF THE SHARPNOSE SEAPERCH, *PHANERODON ATRIPES* (JORDAN AND GILBERT)[1]

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INTRODUCTION

The sharpnose seaperch is one of 19 marine embiotocids occurring in California waters. Apparently abundant in the late 1880's, limited occurrence in sport and commercial catches during recent years has caused most authors to list it as scarce.

A single specimen captured beyond its known northerly limit in 1960, coupled with the appearance of specimens at Monterey Bay, Morro Bay, Cortez Bank, and Baja California, has furnished new information about the species' maturity, food habits, growth, and age. Data on range, occurrence, size, and meristic counts have been expanded and combined with those given in recent literature.

RECORDED RANGE

The range given by Roedel (1953) was from Monterey Bay, California, to San Benito Island, Baja California. A single specimen captured at Bodega Bay on August 11, 1960, extended the northerly limit about 135 miles.

[1] Submitted for publication June 1963.

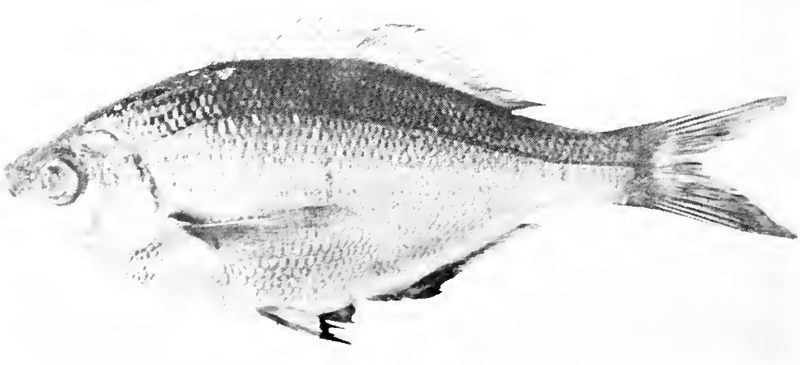

FIGURE 1. Sharpnose seaperch, *Phanerodon atripes*, 188 mm standard length, 9½ inches total length, from Monterey Bay, California. *Photograph by the author, August 1962.*

OCCURRENCE

The sharpnose seaperch was first described by Jordan and Gilbert (1881) from two specimens found at a San Franciso fish market in 1880, which they thought had arrived in a commercial shipment from Monterey Bay. Later, they captured and examined some 200 specimens from the Monterey area.

There appears to be some disagreement as to their abundance, especially in recent years. Prior to the turn of the century, the following accounts were given: Jordan and Gilbert (1882a, p. 50), "abundant in Monterey where large numbers are taken in seines"; Jordan and Gilbert (1882b, p. 595), "Monterey bay; locally abundant"; Jordan and Evermann (1898, p. 1507), "Monterey and banks off San Diego (Cortez Banks) in deeper water than related species; not yet recorded from intervening localities; locally abundant off Monterey"; Eigenmann (1893, pp. 130, 157), "it is the commonest species in Monterey Bay, but does not appear to the south between Monterey and the Cortez Banks."

Higgins and Sette (1921) noted the first intervening occurrence during the summer of 1921, a single specimen found among the commercial surfperch catch in a San Pedro market.

J. H. Wales (W. I. Follett, pers. comm.) recorded sharpnose seaperch in Monterey Bay during 1928. Specimens were taken "commonly" in traps and seines near Hopkins Marine Station, Pacific Grove. Croker (1930) reported upon a 23 cm specimen found in a load of mackerel landed at San Pedro, and said they were uncommon in southern California. Jordan, Evermann, and Clark (1930) listed the species as scarce. Miller (1959, 1961) indicated it was rarely taken. However, John E. Fitch (pers. comm.) stated sharpnose seaperch are taken "fairly frequently, about five per year" by setliners in 65 to 90 fathoms. No data are available on their habitat at these depths. Information on the offshore habitat of the sharpnose seaperch was obtained from Herbert W. Frey (pers. comm.). Two specimens were taken at a night-light station in the vicinity of Bishop Rock, Cortez Bank, approximately 100 nautical miles offshore. These fish were captured on hook and line near the bottom in 6½ fathoms of water. Fathometer tracings showed the bottom was very irregular as is characteristic of the many reefs in the area. Other species taken at this night-light station were: treefish, *Sebastodes serriceps;* yellowtail rockfish, *Sebastodes flavidus;* bocaccio, *Sebastodes paucispinis;* ocean whitefish, *Caulolatilus princeps;* and mola, *Mola mola.*

Knowledge of their inshore habitat in the Monterey area is based on several underwater observations:

1) Two specimens were sighted in the Lover's Point area, Monterey Bay, on October 21, 1961 by Dan Gotshall, marine biologist, California Department of Fish and Game. The pair was very shy and more difficult to approach than other fishes in the area, principally kelp perch, *Brachyistius frenatus.* These sharpnose seaperch seemed to hold a territory among dense growths of kelp, *Macrocystis,* in less than 50 feet of water.

2. On December 21, 1961, Gotshall sighted a school of 10 at Cannery Row, Monterey Bay. This was the first notation of this species in a schooling pattern. They were extremely shy and easily frightened by the approaching diver. The perch occupied a territory among the dense beds of *Macrocystis* near rocky pinnacles in less than 50 feet of water.

3. Lee Hayman, Los Gatos Skindivers, speared four from a school of 10 in the same area off Cannery Row on February 25, 1962.

Other skindivers occasionally report seeing single specimens in association with schools of such other embiotocids as pile perch, *Rhacochilus vacca*; white perch, *Phanerodon furcatus*; and black perch, *Embiotoca jacksoni*.

The species' presence at Bodega Bay and Morro Bay indicates a more diversified habitat. Both bays have sandy bottoms with few small rocks extending beyond depths of 10 feet. The dominant cover is floating debris and pier pilings at depths to 20 feet.

The Bodega specimen was found in a pier fisherman's catch with juvenile copper rockfish, *Sebastodes caurinus*, and shiner perch, *Cymatogaster aggregata*, and was donated by E. C. Johnson, Rio Linda, California. Mollie Van Nortiwick, Tehachapi, California, captured the Morro Bay specimen among a school of walleye surfperch, *Hyperprosopon argenteum*, while pier fishing.

SIZE, AGE, AND GROWTH MATURITY

Prior to this study, the maximum length of sharpnose seaperch was considered about 10 inches, but 2 of 10 specimens measured between 1960 and 1962 were over 10 inches (Table 1). The largest, which measured 11.5 inches (291 mm) and weighed 271 grams, establishes a new size record for the species.

TABLE 1
Lengths and Weights of 12 Sharpnose Seaperch
August 1960-July 1963

Area of Capture	*Date*	*Total length (mm)*	*Standard length (mm)*	*Weight grams*
Monterey Bay	7 Oct. 1962	291	233	271
Monterey Bay	25 Feb. 1962	278	214	–
Monterey Bay	25 Feb. 1962	252	203	–
Monterey Bay	25 Feb. 1962	251	202	–
Monterey Bay	7 Oct. 1962	251	200	210
Monterey Bay	25 Feb. 1962	249	194	–
Bodega Bay	11 Aug. 1960	249	193	–
Monterey Bay	20 Oct. 1962	245	189	194
Monterey Bay	7 Oct. 1962	237	188	159
Cortez Bank	18 Jun. 1963	235	182	135
Morro Bay	11 Jul. 1963	231	181	158
Baja California	31 Oct. 1962	171	124	58

An indication of growth and age was obtained from data given by John E. Fitch (pers. comm.) for four individuals. Two of these, each 249 mm t.l., had five winter rings on their otoliths, while a 278 mm specimen and a 235 mm specimen had seven winter rings.

The Bodega Bay specimen contained 11 embryos interlaced in the ovarian fold. These embryos were completely formed, but their vertical fins appeared greatly elongated. The total lengths of the embryos were from 34 to 36 mm. Ten embryos ranging from 46 to 50 mm total length were removed from the Morro Bay specimen. Their appearance was similar to that described for the Bodega embryos. The presence of embryos during July and August indicates sharpnose seaperch are summer spawners.

FOOD HABITS

The stomachs of the Bodega Bay and four Monterey Bay fish were examined; four contained identifiable material while one was empty. The dominant food in the Monterey area was *Macrocystis*, although isopod and amphipod crustaceans were also noted. The Bodega Bay specimen contained only crustaceans (Cirripedia, Decapoda (bait), and Amphipoda).

The individuals captured by commercial setline are taken on large "rock cod" hooks with squid as the principal bait, while sportfishermen capture them with small hooks using pieces of squid or shrimp.

DESCRIPTION AND MERISTIC DATA

Recent examination of the sharpnose seaperch shows its appearance is closer to that of the white seaperch, *Phanerodon furcatus*, than generally described in the literature. The sharpnose seaperch is olive to sooty-grey dorsally with a reddish overcast due to red to purple markings on the posterior margins of the scales. The ventral surface is silvery-white. The pectoral fins are greyish-white while the caudal fin ranges from greyish-white to a dusky overcast. Sooty-grey to black markings on the pelvic fins may extend over most of the greyish-white to medium-yellow background or may be present on the extreme tips only. Generally, the body is elongated, terminating in a deeply-forked caudal fin. The presence of a sharp nose, as the common name implies, may be misleading. The head features may appear more pronounced in some specimens, but generally their features are similar to those in Figure 1.

Meristics from 16 specimens (Table 2) were compared with data given by Tarp (1952). Counts showed dorsal soft rays, anal soft rays, and pectoral rays have a greater range than he noted for six specimens. Gill raker counts, not made by Tarp, ranged from 13 to 15. The data suggest no latitudinal differentiation for the northern specimen. X-rays of one specimen revealed 37 vertebrae, 15 precaudal plus 22 caudal.

SUMMARY

A sharpnose seaperch captured at Bodega Bay in 1960 extends the known range north about 135 miles.

There have been increasing reports of this species in recent years, following a long period of presumed scarcity. An 11.5-incher was a new size record. The presence of embryos in two females indicates they spawn during summer.

Food consists of both algae and crustaceans.

Meristic data from 16 specimens suggest no significant latidudinal variation.

TABLE 2

Meristic Data from 16 Sharpnose Seaperch

Origin of specimens examined	Dorsal spines		Dorsal soft rays				Anal rays					Pectoral rays				Gill rakers (lower limb)			Lateral line pores					
	X	XI	21	22	23	24	26	27	28	29	30	19	20	21	22	13	14	15	63	64	65	66	67	68
Bodega Bay (1)	1				1			1					1					1						1
San Francisco (1)*	3	1	2	2			1		1	1	1	2	2			1	3							
Monterey Bay (8)†	6	1	3	1	1		1	1	3			2	5	1		3	1		1	1		1	1	
Morro Bay (1)	1				1						1	1						1				1		
Cortez Bank (1)	1			1					1			1					1							1
Baja California (1)	1			1				1							1		1		1					
Summary from Tarp (6)	X	XI		22 -		24		27			30		20		22		**				63	68		

All counts patterned after Tarp (1952). The number in parentheses indicates the number of specimens examined by area. The following counts are invariable: anal spines III, pelvic rays I + 5, and caudal rays 16.

*The data for the "San Francisco" specimens are unknown, but catalog numbers from the California Academy of Sciences indicate they were taken in the late 1880's.

**Data not given by Tarp.

†Incomplete counts of dorsal spines, gill rakers, and lateral line pores for Monterey Bay fish due to condition of specimens taken by speargun.

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LANDINGS ESTIMATES OF CALIFORNIA'S MARINE RECREATIONAL SALMON FISHERY[1]

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INTRODUCTION

Since 1936, the Department of Fish and Game has intermittently published a series of statewide angling estimates, based on responses to postal-card questionnaires mailed to a systematic sample of angling license buyers. A means of determining the accuracy of postal-card estimates has not been available, but personnel experienced in salmon fisheries believe such estimates consistently exaggerate salmon landings.

The primary purpose of postal-card estimates is to determine trends of catch and effort to serve as a guide to research and management. Although index numbers would satisfy this purpose, postal-card estimates have, unfortunately, been published as numbers of fish caught, not as index numbers.

In the marine recreational salmon fishery, sampling of landings during several seasons has provided a basis for better catch estimates. These have been lower than those based on postal-card questionnaires. Because both sets of estimates have been published, confusion exists as to the actual size of California's ocean sport salmon landings. Presented here are official estimates of these landings for the years 1947 through 1962 and a brief discussion of how they were obtained and of how they will be obtained in the future. These estimates supersede and replace any and all estimates published previously.

The Department of Fish and Game is indebted to skiff livery and launching facility operators who contributed and continue to contribute to this program by keeping counts of salmon landed at their facilities. Without such assistance, an accurate assessment of ocean recreational salmon landings would be an economic impossibility.

The ocean sport salmon fishery is divided into two segments: the partyboat fishery and the so-called skiff fishery which actually includes all non-partyboats. Many of these privately-operated boats are larger than what is commonly called a skiff, and a few compare favorably in size with the largest partyboats. Partyboat anglers pay a fee for a day's fishing, and the operator of each such vessel is licensed and required by law to record and report the number and species of fish landed. Periodic spot checks have indicated that cumulative errors and omissions are minor. Of concern, then, is the number of salmon taken by anglers not fishing from partyboats.

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Most of the estimates of skiff landings were made by using random sampling plans. At several locations, counts were obtained from log books provided by the Department to selected skiff livery and launching facility operators. A few estimates were based on periodic observation coupled with a knowledge of the fishery. California's marine recreational salmon fishery is pursued from a large number and wide variety of access points. It would be too expensive to sample statistically all of them with trained samplers, but reasonably accurate estimates can be obtained by more economical methods. Four years (1955, 1956, 1960, and 1961) of extensive sampling produced catch estimates for the skiff fishery which ranged from 54 percent of the 1955 partyboat fishery to 37 percent of the 1961 fishery (Table 1).

Landings made by the skiff fishery averaged about one-third of the total. A slight decrease in skiff contribution has occurred as total landings declined. Partyboats can range farther from port and are less dependent on weather conditions than skiffs. For this reason, we might expect that during years of poor fishing or periods of bad weather, skiff fishery landings would tend to decline to a greater extent than those of the partyboat fishery.

POSTAL-CARD ESTIMATES

Landings estimates based on mailed questionnaires include responses from both partyboat and skiff anglers. Estimates of salmon landings based on postal-card responses and estimates based on partyboat land-

TABLE 1
California Ocean Sport Salmon
Partyboat Landings and Skiff Landings Estimates
(in thousands of fish)

Year	*Partyboat landings* *	*Skiff landings* †	*Ratio Partyboat : Skiff*
1955	129	70	1 : 0.54
1956	115	61	1 : 0.53
1957	45	no data	
1958	53	no data	--
1959	56	no data	-
1960	38	18	1 : 0.47
1961	43	16	1 : 0.37
1962	88	no data	--

* From log reports. Rounded to nearest thousand fish.
† Estimates based on landings sampling. Rounded to nearest thousand fish.

TABLE 2
California Marine Sport Salmon Fishery
Comparison of Total Landings Estimates Compiled by Two Methods
(in thousands of fish)

Year	*A* *Reported partyboat catches plus estimated skiff catches*	*B* *Estimates based on postal-card responses*	*C* *Col. B as percent of Col. A*
1955	199	648	326 percent
1956	176	500	284 "
1960	56	299	534 "

TABLE 3
Postal-Card Estimates of Marine Sport Salmon Landings and Partyboat Catch Reports, 1955-1960
(in thousands of fish)

Year	A *Partyboat catch reports estimates*	B *Postal Card estimates*	C *Col. B as percent of Col. A*
1955	129	648 *	502 percent
1956	115	500	435 "
1957	45	480	1067 "
1958	53		"
1959	56	421 †	752 "
1960	38	299 †	787 "

* Total survey suspect—no publication.
† Publication suspended.

ings plus fishery sampling are available for 1955,[2] 1956, and 1960 (Table 2). Postal-card estimates ranged from 2.8 to 5.3 times larger than those based on logs plus fishery sampling.

Postal-card estimates and partyboat catch reports are available for comparison during the period 1955 through 1960, with the exception of 1958 (Table 3). It seems probable that both partyboat and skiff anglers exaggerate their success when responding to mailed questionnaires. To meet their primary purpose, postal-card estimates must at least reflect trends in landings. They do not do so in this fishery.

For example, the marked drop in partyboat landings from 1956 to 1957 was undoubtedly accompanied by a similar or greater decline in landings of the less efficient skiff fishery, yet this combined drop was not reflected in postal-card estimates. The 1955 postal-card survey was not published because of changed format and inconsistencies in response, but it exaggerated landings less than did the 1957 survey when response was considered acceptable. The postal-card estimate in 1955 was 5.0 times the reported partyboat catch as compared with 10.7 times in 1957.

Because the Department's Marine Resources Branch is now responsible for salmon and steelhead catch estimates and because of large and inconsistent differences between postal-card estimates and those based on partyboat reports plus sampling, salmon and steelhead will no longer be included in the statewide postal-card angling survey.

OFFICIAL ESTIMATE OF OCEAN SPORT SALMON LANDINGS, 1947-62

The following official estimates of California's marine sport salmon fishery were first reported by Wendler (1960) who covered the period from 1947 to 1958. When his paper went to press, landing figures for the 1958 season were incomplete. Final estimate for 1958 season is 80,000 salmon (Table 4).

[2] In 1955, format of the questionnaire varied from that used in previous years. Estimates obtained by the new questionnaire were not published because of inconsistencies in manner of response. Subsequent surveys employed a questionnaire similar to that used prior to 1955.

TABLE 4
Official Landings Estimates for California's Marine Recreational Salmon Fishery, 1947-1962
(in thousands of fish)

Year	*Landings*	*Year*	*Landings*
1947	5	1955	199
1948	12	1956	176
1949	25	1957	69
1950	62	1958	80
1951	111	1959	84
1952	133	1960	56
1953	152	1961	59
1954	185	1962	132

During the late 1940's, California's marine skiff fishery was in its infancy. In the early 1950's, a large increase in marine skiff use was noted, and first measurements of their contribution to total sportfishery landings were made in 1955 and 1956. Total landings estimates for those years in which no sampling was done were made by assuming that from 1947 through 1950 the skiff fishery took 10 percent of the total ocean sportfishery landings and that in 1951 and later years it has taken one-third of the total. Marine Resources Branch presently maintains a logbook system among selected skiff liveries and launching facilities. When this check system indicates occurrence of a significant change in the skiff contribution to total landings, another full-scale sampling program will be initiated.

SPECIES COMPOSITION OF LANDINGS

Species of salmon commonly taken on the California coast are king *(Oncorhynchus tshawytscha)* and silver *(O. kisutch)*, but king salmon predominate. This is particularly true from San Francisco south, where most ocean sportfishing activity occurs. For this reason, sport landings consist primarily of king salmon. Fishery sampling during 1955, 1956, 1960, and 1961 indicates that silver salmon make up approximately 10 percent of the total sport catch. Commercial salmon fishery landings samplers, as time permits, make observations of sportfishing activity in their areas. A drastic change in species composition of sport landings would be noted immediately by these samplers.

SUMMARY

Comparison of marine recreational salmon landings estimates based on postal-card questionnaires with those based on fisheries sampling demonstrates greater reliability of the latter as measures or indices of landings. Since 1960, salmon and steelhead have been omitted from statewide postal-card angling surveys.

Landings sampling has established partyboat logs as a reliable index of marine recreational salmon landings. Landings subsequent to 1951 have been estimated by increasing partyboat landings by 50 percent. This practice will continue until such time as the monitoring system now in use should reveal a significant change in the skiff fishery contribution to total landings.

Marine recreational salmon fishery landings are composed of approximately 90 percent king salmon and 10 percent silver salmon. These percentages have been and will be used until such time as the monitoring system reveals a significant change in species composition of landings.

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OBSERVATIONS ON SPAWNING PACIFIC SARDINES[1]

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While the U.S. Bureau of Commercial Fisheries research vessel, *Black Douglas*, lay at anchor in South Bay, Cedros Island, Baja California, Mexico, scientific personnel aboard observed unfamiliar behavior by a school of Pacific sardines, *Sardinops caeruleus* (Girard). This observation took place on August 16, 1958, between dusk (approximately 1830 PST) and 2225 PST. Collection of almost 200 fish in "running ripe" condition, i.e. eggs and milt flowing freely, together with plankton-net collections of newly-spawned eggs indicated sardines were spawning. The summarized behavior observations and collections of fish and eggs are documented in this report.

Both observations and collections were made while investigating late-summer (August-September) spawning of sardines off central Baja California. This secondary spawning period has occurred with some regularity in past years in addition to the species' usual spawning period between February and June. Investigating late-summer spawning has been part of a continuing census of sardine egg and larval populations, a facet of the California Cooperative Oceanic Fisheries Investigations (CalCOFI).

BEHAVIOR

Sardine activity began immediately after dark throughout the bay. The school was spread in a loose aggregation at or near the water's surface. Individual fish darted about apparently at random, and often leaped clear of the water causing the surface to present the broken appearance of having pebbles continuously dropped upon it. The sound was similar to that of a rain shower on calm water. A light suspended beside the ship made it possible to observe the fishes' movements to a depth of 3 meters. Their behavior consisted of apparently random excited motion. An individual fish would feed occasionally on organisms attracted to the light, and some were taken there by hook and line; however, none was observed releasing eggs or sperm.

I have discussed the species' schooling behavior with commercial sardine fishermen and others who have caught them for bait. Their observations, substantiated by my personal experience, indicate schooling behavior generally will follow a specific pattern determined by the school's immediate circumstance. The lack of published material on general Pacific sardine behavior makes it desirable to describe some major patterns to contrast with what I have tentatively assessed as spawning behavior.

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A normally moving sardine school is generally crescent shaped when viewed from above. This applies either when the fish are actually seen, or when their presence is indicated by surface disturbances during the day or by bioluminescence at night. The crescent moves with its leading edge convex as a result of individual fish behavior. MacGinitie and MacGinitie (1949: 420) say: "Sardines possess the interesting trait of orienting themselves so that they are a little behind and to one side of the fish that is ahead of them. This keeps them in rather long and somewhat slender schools."

This pattern is changed only slightly when the fish are filter-feeding. Their movements are quickened and the gills are flared often to allow water to flow more easily past the gill rakers and out the gill openings. When sardines are particulate feeding the school tends to break up and the movements of individuals are not oriented to those of nearby fish.

Schools occasionally may appear as irregular areas, usually much longer in one dimension and tending to remain continuous instead of breaking up into linearly associated smaller schools.

The schooling pattern of sardines under predator attack differs considerably from other schooling behavior. The school assumes the shape of a pliable sphere which bulges, indents, and flows when attacked. The top of the sphere may be forced completely out of water under pressure of predation. Any fish which becomes disoriented and swims away from the sphere usually is captured immediately. The school reacts toward the rush of an individual predator by opening before the rush and closing behind it, thus making it difficult for a predator to scatter the fish and allowing the school to retain its continuity against further attack. These observations are confirmed in part by Allen (1920) and Fink (1959).

SPAWNING

One-hundred ninety-eight sardines were collected in South Bay by a gill net and hook and line. The gill net consisted of a single piece of $2\frac{1}{2}$-inch (stretched) nylon webbing 30 feet long by 28 feet deep. Two 1,000-watt incandescent bulbs were hung below reflectors off the stern to attract fish. The net, floating vertically, was streamed from either quarter of the ship, then tied off to act as a barrier in the path of fish attracted to the light. After finding sardines in the first haul in spawning condition, net collections were augmented by hook and line fishing.

Fish were caught by hook and line using two types of lures on a light freshwater bait-casting rod and reel filled with 12-pound test nylon mono-filament line. Either a string of six bright shiny No. 8 hooks spaced 4 inches apart, or a patented "Paulas" lure was fastened to the terminal end of the line. A Paulas lure utilizes four hooks covered with bright colored yarn treated with an unidentified fish attractant. These hooks also were spaced 4 inches apart. Either string of hooks was weighted with an ounce of lead then jigged slowly up and down under the light. Sardines were somewhat reluctant about striking either bare hook or lure, but did so frequently enough to prove both are useable collection tools.

This collection of spawning Pacific sardines was the largest on record to that time. Clark (1934: 5) stated that during 12 seasons (1919-1931) of sampling commercial sardine catches at San Pedro, only 39 ripe or nearly ripe females were collected. Four ripe female sardines were taken by California Department of Fish and Game personnel from the research vessel, *Yellowfin*, in south Sebastian Vizcaino Bay on May 5, 1950 (California Division of Fish and Game, log of cruise 50Y4, 1950); a ripe female and two ripe male sardines were taken off San Cristobal Bay, Baja California (Miller, 1952); two small samples of spawning sardines were taken in Sebastian Vizcaino Bay in August, 1953 (California Department of Fish and Game, 1953); sardines in spawning condition (73 of 74 males, 25 of 26 females, K.F. Mais, pers. comm.) were collected off Punta Abreojos early in 1954 (California Department of Fish and Game, 1954); and two ripe female sardines were taken in 1958 by U.S. Bureau of Commercial Fisheries personnel while sampling commercial landings at Ensenada, Baja California.

A random sample of 50 of the 198 fish taken in South Bay were measured and aged. Gonads were examined to determine sex and degree of development. Of 43 females, 34 were about to spawn or partially spawned, four were completely spawned out, and five were not in spawning condition. All seven males were ripe. Fish ranged from 187 to 220 mm s.l. and averaged 200 mm. The age composition of the sample was: 2-year-olds (1956 class), 8 percent; 3-year-olds (1955 class) 42 percent; 4-year-olds (1954 class), 44 percent; 5-year-olds (1953 class), 6 percent.

Sardines from the South Bay collection were older than fish taken by boats based at the Cedros Island village cannery. A random sample of 50 sardines caught on August 15, 1958, within Sebastian Vizcaino Bay ranged from 142 to 178 mm s.l. and consisted of 82 percent 1-year-old and 18 percent 2-year-old fish (1957 and 1956 classes respectively). Routine sampling of the catch at this cannery throughout 1958 showed these smaller, younger fish predominated while larger, older ones like those taken in South Bay appeared only incidentally.

After collecting the ripe sardines, samples of planktonic sardine eggs and larvae were taken in a 3-minute (2229-2232 PST) oblique plankton haul with a 1-meter net, from 20 meters to the surface (both oblique haul and net are described by Ahlstrom, 1953:4), and a 10-minute (2235-2245) circular surface haul with the same net in the same area.

The depth distribution of sardine eggs collected in South Bay parallels Ahlstrom's (1959a:140) conclusion that sardines spawn somewhat below the surface. The oblique haul contained an estimated 5,088 eggs, 67 percent were newly spawned (stage I: Ahlstrom, 1943) and the remainder approximately 1 day old (stage VI). In comparison, the surface tow took approximately 7,180 eggs (both tows were fractioned to 25 percent of original size before counting), of which only 3.5 percent were newly spawned, indicating that newly spawned eggs were more abundant somewhat below the surface.

The estimated 3,360 stage I eggs taken in the oblique haul constitute the largest collection of newly spawned sardine eggs to date, in fact, larger than the total of all such eggs previously collected by the CalCOFI program. Only 10 sardine larvae were taken in both hauls.

Miller (1952) utilizing a ripe female and two ripe males taken in April 1952 off San Cristobal Bay, Baja California, stripped 3,000 eggs from the female and fertilized them with sperm from one of the males. The eggs were incubated, hatched, and the larvae developed through the pre-larval stage. Sardine eggs at spawning lack the wide perivitelline space characteristic of all but their youngest stages in plankton collections. Miller followed the increase in diameter of the outer egg membrane (there is no corresponding increase in yolk diameter) from approximately 1.10 mm at fertilization to a maximum of approximately 1.80 mm by 10 hours after fertilization. There was no subsequent increase in diameter. Miller also determined that cleavage began about $1\frac{1}{2}$ hours after fertilization.

Ahlstrom (1943) described sardine egg development from material taken in repeated plankton hauls. Both Ahlstrom's and Miller's egg diameter measurements are presented with like measurements of eggs taken in the South Bay plankton collections (Table 1). The size of precleavage eggs from all three sources compare favorably. The diameters of older eggs showed greater variation; however, Ahlstrom, using more extensive materials than Miller, found an average diameter of 1.70 mm which was intermediate between Miller's value (1.83 mm) and that which I found (1.62 mm).

TABLE 1

Comparison of Sardine Egg Diameter Measurements
(all material measured after preservation)

	Hours after fertilization	*Average diameter of eggs (mm)*	*Range in egg diameters (mm)*	*Number of eggs examined*
Precleavage eggs	$0–1\frac{1}{2}$			
Ahlstrom (1943)	"	1.20	1.02-1.38	591
Miller (1952)*	"	1.26	1.10-1.41	20
South Bay (oblique haul)	"	1.23	0.97-1.45	104
Developing eggs	10 to hatching			
Ahlstrom	"	1.70	1.35-2.05	ca 1000
Miller	10	1.83	1.71-1.90	10
South Bay (surface tow)	24-26	1.62	1.45-1.73	100

* 0 and 1 hour observations combined.

DISCUSSION

Although the sardine behavior described took place simultaneously with spawning, as evidenced by fish and egg collections, there was no directly observable link between them. Such a link can only be inferred, since the visibility was limited to only 3 meters and the fish spawned somewhere between there and 20 meters. Indeed, John Radovich of the California Department of Fish and Game has indicated (pers. comm.) that he and other Department biologists have observed the behavior described without succeeding in collecting any accompanying evidence of spawning. A recent communication from K. F. Mais of the California Department of Fish and Game reveals that on May 1, 1962 off Santa Catalina Island, biologists aboard the *Alaska* took a 50-fish sample of sardines in an advanced state of maturity, but were unable to collect any spawned eggs because of lack of equipment. He further states that school behavior as seen beneath the light was typical of non-spawning schools in the area where the fish milled calmly in a moderately compact school between 8 and 30 feet below the surface.

Apparently little or no spawning took place the night of August 16 in Southeast Bay, located immediately east of South Bay. Eight sardines were caught there and all were spent. One oblique net haul and one surface tow were taken but only 34 eggs in varied stages of development were collected. The oblique haul collected 841 larvae of varied ages, however.

I wish to acknowledge the assistance of other investigators of the La Jolla Biological Laboratory who helped examine the sardine and egg collections. Gonad condition was determined by J. S. MacGregor, and the developmental stages of eggs collected in the plankton tows by D. Kramer and E. H. Ahlstrom.

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NOTE

SPAWNING OF THREADFIN SHAD, *DOROSOMA PETENENSE*, AT LOW WATER TEMPERATURES

Observations at two large warmwater reservoirs, Pine Flat Lake, Fresno County and Millerton Lake, Fresno-Madera counties, California, provided important information on the lower water temperature limits at which threadfin shad spawn. Previous published records (Kimsey, 1958) indicate only that spawning occurs at approximately 70° F. and do not define the temperature range.

The first series of observations was made at Pine Flat Lake on April 25, 1963 following a heavy rainstorm. Shad were observed spawning at 7 AM, when the surface water temperature was 58° F., and at 3 PM when the temperature was 62° F.

The shad collected in small, dense schools under floating brush and small logs loosened by the rising water. The spawning fish swam rapidly near the surface, frequently jumping out of the water, and occasionally impaling or entangling themselves in debris. This activity was noted on five different occasions. After each observation, the debris was lifted and many eggs were observed adhering loosely to it.

One school was followed along the surface and spawning activity was noted twice in 20 minutes. The first spawning occurred in debris well out into the lake, while the second spawning occurred at the water's edge where many shad became stranded on shore. Each spawning period lasted about 3 minutes.

A second observation of spawning was made on May 13, 1963 at Millerton Lake. There shad spawned on gillnets when the surface water temperature was 64° F.

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1958. Possible effects of introducing threadfin shad (*Dorosoma petenense*) into the Sacramento-San Joaquin Delta. Inland Fish. Admin. Rept. no. 58-16, 21 p. (mimeo.).

R. R. Rawstron, Inland Fisheries Branch, California Department of Fish and Game, August 1963.

BOOK REVIEWS

Studies of Alaska Red Salman

Edited by Ted S. Y. Koo; University of Washington Press, Seattle, 1962; viii + 469 pp., 170 figs., $8.50.

This volume consists of nine papers by present and former staff members of the Fisheries Research Institute, University of Washington. Eight are based on work in the Bristol Bay area, the ninth concerns the red salmon of Kodiak Island. Seven of these articles are based on four doctoral theses completed between 1955 and 1959. The papers were re-titled and revised but unfortunately, ". . . because of the time lapse between dates of submission and publication, new, related literature could not find its way into the revisions."

All are valuable additions to fisheries literature, and the University is to be commended for making them available this way rather than through such cumbersome processes as inter-library loans and photographic copying. Each article has its own abstract.

The nine articles are:

1. *The research program of the Fisheries Research Institute in Bristol Bay, 1945-1958*, by W. F. Thompson; 36 pp. Dr. Thompson was director of the F.R.I. from its founding until 1958. He says, ". . . this paper is not a statement of the present programs of research in Bristol Bay; it rather expresses personal ideas or opinions of the writer. These opinions may help to explain what has happened in the Nushagak red salmon run and may be of use to others faced with planning like tasks of research. The purpose in describing this program is to raise questions, not to settle them."

2. *Age designation in salmon*, by Ted S. Y. Koo; 12 pp. In this paper an effort is made to bring some order out of the confusion resulting from using many different formulas to record the life history of salmon and trout from their scales.

3. *Age and growth studies of red salmon scales by graphical means*, by Ted S. Y. Koo; 74 pp., 41 figs. The graphical method described serves to minimize personal bias in scale reading and markedly increases reliability; it can be applied to other species of fish.

4. *Differential scale characters among species of Pacific salmon*, by Ted S. Y. Koo; 14 pp., 3 figs. This should make it possible for anyone to identify the scales of the five North American Pacific salmon with fair consistency. Unfortunately, steelhead are not included.

5. *The effect of altered sex ratios on the spawning of red salmon*, by Ole A. Mathisen; 110 pp., 43 figs. Gill nets used in Bristol Bay are highly selective towards male red salmon. Mathisen describes experiments in which red salmon spawned while confined in pens in a stream. The sex ratio varied from three males per female to 30 females per male. Only at the 1:30 ratio did the male show a temporary lack of fertility. The fish adapted their spawning procedure to the existing sex ratio.

6. *Studies of red salmon smolts from the Wood River Lakes, Alaska*, by Robert L. Burgner; 68 pp., 27 figs. "Red salmon smolts . . . were studied to determine fluctuations in abundance, growth, and survival, and to ascertain causes of the fluctuations."

7. *Sampling red salmon fry by lake trap in the Wood River Lakes, Alaska*, by Robert L. Burgner; 34 pp., 13 figs. Floating traps were used to measure the abundance of young red salmon during their residence in the lakes. Variations in abundance within seasons and between seasons, and competition between young salmon and sticklebacks, are among the subjects discussed.

8. *Photographic enumeration of red salmon escapement*, by Ole A. Mathisen; 24 pp., 9 figs. This briefly describes the method of counting upstream migrating salmon from towers and then gives a detailed description of a time lapse photographic method which should enable an observer to man more than one station.

9. *Estimation by tagging of the size of migrating salmon populations in coastal waters*, by Donald Edward Bevan; 97 pp., 34 figs. This work was done to study the migration patterns, abundance and mortality of Kodiak Island red salmon. It will also serve as an excellent guide to fisheries workers wishing to set up a tagging experiment and analyze the results.—*Donald H. Fry, Jr., California Department of Fish and Game.*

Introduction to Animal Parasitology

By J. D. Smyth. Charles C. Thomas, Publ., Springfield, Ill., 1962; xx+470 p., 168 figs; $11.50.

The author has taken a new and fresh approach for his text. Just as many other biological sciences have embraced physiology and chemistry, here parasitology has encompassed these aspects for the first time. This is a divergence from the classical format that has been limited to discourses on anatomical features and life cycles. Yet it is one step short of the completely rounded and modern biological approach which includes not only the environment, but all of the ecological factors.

The usual definitions and relationships of the invertebrates living on or within vertebrates is the subject of the first chapter. Chapter 2 deals with the habitats and environments of parasites. Chapters 3 through 10 are concerned with the protozoan parasites, and 11 through 31 with the helminths. These are followed by two chapters written about the host's reactions and immunological response to the invading organisms. Two final chapters contain useful information about cultivation of endoparasites *in vitro*. An appendix lists the animal parasites of the laboratory mouse and rat. All illustrations are line-drawings, some were borrowed from other texts, but many are new and excellently done.

This is, by title, an introductory work. My question is, "for whom is the subject being introduced"? If it is designed for those who will go on in parasitology, then it is well and good. However, if it is intended for students who will have no further contact with the subject, there is a serious gap. Dr. Smyth emphasized the descriptions of species that can be maintained in laboratory animals. He elaborated in great detail their morphology and life cycles, but at the expense of those parasites of most importance to human or animal health. As an example, the rat hookworm, *Nippostrongylus muris* is given five pages, whereas the hookworms of man, *Ancylostoma duodenale* and *Necator americana*, are contained within two pages. My conclusion is that as an adjunct to a laboratory course the book would be invaluable. Its use as a taxonomic reference is limited. The accounts of the parasites' physiology and biochemistry are stimulating and informative.—*Merton N. Rosen, California Department of Fish and Game.*

Marine Molluscan Genera of Western North America

By A. Myra Keen. Stanford Univ. Press, Stanford, Calif., 1963; 126 pp., illustrated; $4.50.

This small book has more to offer between its covers than dozens of other molluscan publications that are two to ten times as voluminous. Biologists, malacologists, ecologists, concholgoists, amateur shell collectors, book lovers, and everyone else who has an interest in determining the identity of a west coast marine snail or clam will find it indispensable.

The introduction explains the book's conception, organization, symbols, and problems. This is followed by 70 pages of illustrated keys that actually work. Almost as useful—or even more useful, depending upon one's needs—are the systematic and ecologic lists. A glossary, a bibliography, and an index complete the volume.

In running various items through the illustrated keys I encountered very little difficulty except with a few atypical or aberrant specimens. "*Tegula*" *regina* insisted upon keying out to *Turcicula*, and I couldn't figure which path to take when I needed to know the shape of a nuclear whorl that wasn't there. The author intimates that the book's weakest section is the systematic list of cephalopods, and in this I concur.

I was especially pleased with the 11 pages of ecologic information Dr. Keen has included. I only hope her efforts along this line will spur the book's users into

divulging their intimate knowledge of molluscan ecology if it differs from or adds to the data supplied in this book.—*John E. Fitch, California Department of Fish and Game.*

Ichthyalogy, the Study of Fishes

By Karl F. Lagler, John E. Bardach, and Robert R. Miller, John Wiley & Sons, Inc., New York, 1962; xiii + 545 pp., illustrated; $12.50.

Ichthyology, the study of fishes is unquestionably the most worthwhile basic textbook on the subject in print today. In the preface, the authors point out they intended it for college use. They overlook its value to the practicing (professional) ichthyologist or fishery biologist. In fact, because so many of our present-day fishermen are well-educated and well-informed, I suspect they too should be included among the book's potential audience.

To quote the authors, "Early chapters . . . introduce the diversity of fishes and show the position and content of the major groups, their classification, relationships, and basic structure, with emphasis on living fishes. . . . [Succeeding chapters] describe the comparative anatomy and physiology of the classical ten bodily systems and their integration into the whole fish. Principles of genetics, evolution, systematics, ecology and ichthyogeography comprise [later chapters]. . . ." Each section of each chapter, although quite brief, seems adequate. A list of special references appears at the end of each chapter for those wishing to pursue a subject further.

Omissions, oversights, and such, are difficult, but not impossible, to find, as exemplified by the sinistral *Pseudopleuronectes* on page 19. In several places, I had considerable difficulty extracting the "meat" from the circuitous phraseology so typical of passive prose.

Regardless of these undesirable features, the book deserves a rating of "superior." It should be required reading for all fishery biologists, myself included. In fact, lately I have been budgeting my time to include a do-it-yourself refresher in *Ichthyology, the study of fishes.—John E. Fitch, California Department of Fish and Game.*

Advances in Ecological Research

Edited by J. B. Cragg, Academic Press, London, 1962; xi + 203 p., illustrated; $7.50.

This is the first volume of a proposed series of comprehensive papers selected to provide biologists with a balanced picture of what is taking place in the field of ecological research. We have found it a useful contribution to our own work.

The first paper by A. Macfadyen, University College, Swansea, England, on "Soil Arthropod Sampling" includes a discussion of sampling design and practical solutions to sampling problems applicable to many kinds of investigations. The description of methods of sorting arthropods from soil includes ideas useful to biologists working on benthos.

In the second paper, "Successive Approximation in Descriptive Ecology," M. E. D. Poore, University of Malaya, emphasizes the importance of a sometimes forgotten part of the scientific method—that of developing and modifying hypotheses with observations before plunging into rigid quantitative statistical description and analysis.

L. B. Slobodkin, University of Michigan, in a paper entitled "Energy in Animal Ecology" reviews some of the theories developed and used by workers in this relatively new field. It is an excellent review of a complex subject.

The longest paper, "Quantitative Ecology and the Woodland Ecosystem Concept," is written by J. D. Ovington, Monk's Wood Research Station, Huntingshire, England. The author describes the organic matter and energy dynamics and water and chemical circulation in woodland ecosystems. The description will be useful to those who seek understanding of man's effects on our own forests.

Each of the four papers is really an interpretive review of work done on a specific subject. The series promises to provide the fishery or wildlife biologist with a thought provoking look at related fields.—*D. W. Kelley, California Department of Fish and Game.*

Fishing Tackle and Techniques

By Dick Wolff, E. P. Dutton & Co., New York, 1961; 186 pp., illustrated; $4.95.

Although this book is written primarily for beginners, even experienced anglers will glean some worthwhile pointers. Author Dick Wolff leaves no doubt in the reader's mind that he knows his subject well, and writes with skill about it.

A chapter each is devoted to techniques of spinning, spin-casting, bait-casting, and fly fishing. One gains the impression that the author is concerned predominantly with freshwater rather than salt water fishing. An interesting addition at the close of each chapter is a question and answer section covering those queries most commonly asked by neophytes of the art.

All in all, the book's general coverage is good, but it will not delve deeply and completely enough to satisfy the angler with interests in specific fish species and how to capture them. *Willis A. Evans, California Department of Fish and Game.*

Tropical Inland Fisheries

By C. F. Hickling, John Wiley & Sons Inc., New York, 1961; xiii + 287 pp., 62 black & white figures, 6 color plates; $7.25.

In this relatively small book, the author has packed a surpising amount of material on tropical fresh waters and their chemistry, physics, and fisheries. The author has gathered from world-wide literature, but the most important source is his own knowledge.

The first eight chapters deal with the physics, chemistry, and biology of tropical streams, lakes, swamps, and impoundments, and include descriptions of the effects of human activities on such waters. Various factors promoting and limiting production are discussed.

A discussion of fish migrations leads to one on dams, fishways, and the behavior of fish in the presence of such artifacts. The author concludes, "In practice, the salmon alone seems to warrant the expense of fish-passes, and this is a fish of temperate rivers. Probably the Hilsa will also need passes in the Indian rivers." This statement seems too all-inclusive, but possibly there is little need for fishways in the tropics. Many fish which accumulate in large numbers below a dam seem to have no compelling biological need to pass.

The final two-thirds of the book describes a large array of tropical inland fisheries in many parts of the world but primarily those of the eastern hemisphere. Sport fisheries are not discussed.

The fisheries are divided into those of rivers, deep lakes, shallow lakes, and swamps. A chapter is devoted to flood fisheries—harvesting fish which move out of the low water channels and feed on vast areas of flat lands submerged by the annual floods in many parts of the tropics. The methods of fishing the flooded areas range from primitive to sophisticated and highly organized (though with little or no mechanization). The quantities taken are huge. The Grand Lac area of Indo-China produces about 150,000 tons per year from the flood-fishery of the Mekong River. The delta of the Middle Niger (West Africa) produces about 45,000 tons per year. As the author states, "These are impressive figures in any fishery statistics."

There are descriptions of many fisheries, the more detailed of which may discuss not only the gear and its use, but marketing problems, methods of preservation, overfishing or underfishing, the limnology of the area or whatever available information the author decided would best illustrate a point. Headings are used for individual fisheries, sub-headings are less consistently used. More consistency and more sub-headings would have made it easier to extract wanted material.

The bibliography of 148 references is exasperating to use—the references are not in alphabetical or chronological order and seldom give any hint of the size of the paper listed.

The index leaves a bit to be desired. As an example, it does not list "Outboards," "Motors," or "Engines" in spite of their great importance in many areas. References to these items were found under "Mechanization of fishing craft."

In spite of these weaknesses, the book is a highly important contribution to understanding tropical fresh-water fisheries and is a must for anyone interested in this subject.—*Donald H. Fry, Jr., California Department of Fish and Game.*

Industriol Fishery Technology

Edited by Maurice E. Stansby, Reinhold Publishing Corp., New York, 1963; x + 393 p., illustrated; $12.

Industrial Fishery Technology is a comprehensive text covering all major phases of the modern United States fishing industry. The manner in which this book is written will make it invaluable to both the student and professional fishery worker alike. The text covers a wide variety of information well, and it is presented in a logical and easy-to-follow manner. Some of the fisheries are covered lightly but in

most cases similar fisheries are covered in sufficient detail to fill in where the information is lacking.

Each of the 26 different writers contributing material for the book is a specialist in the field in which he has chosen to write. There is some overlap in subject matter, as is often the case in closely related fields, but the viewpoints of the different authors give the reader a much better understanding of the industry.

The book is divided into five major sections. Part I is devoted to chapters on the background of the major United States fisheries and in general the methods most often employed for harvesting the resource. Part II describes the 16 most important fisheries by value and the major products they produce. Part II also includes some of the mose important minor fisheries including the seal and whale industry.

In Part III the industrial products industry and the major industrial by-products are discussed, in particular fish meal and oil production. Part IV includes chapters on the technology of food preservation as it is practiced by the modern fishing industry and stresses the importance of developing new processing methods for handling fresh fish and shellfish. In Part V the value of food technology in the industry is reviewed as well as the part chemistry and microbiology play in determining spoilage, nutritive value, and chemical composition of the products and by-products and how they can best be utilized.

In addition to a list of references at the end of each chapter, the last chapter of the book is devoted to a general bibliography of the most important references in each subject classification. *Emil J. Smith, Jr., California Department of Fish and Game.*

An Introduction to Scientific Illustration

By Charles S. Papp, 3324 Inverness St., Riverside, Calif., 1963; 212 pp., illustrated; $5.75 (paperbound).

No one will learn to be a talented artist by perusing the contents of this book, but everyone who is willing to devote some time to it should be qualified to illustrate a manuscript or book to good advantage. The author has used nearly 800 illustrations to demonstrate and explain the various techniques and methods he discusses. All illustrations are accompanied by short lists of technical information and tools or material used to make the original.

A few of the chapter headings will give an idea of the book's varied scope: "Illustrations as teaching aids," "Selecting the proper dimensions," "The need for an art editor," "Making graphs," "Selection of letters and symbols," "The use of tones," "Biological illustrations," "Botanical illustrations," and "Paleontology illustrations." Finally, there are details on printing processes, and page dimensions are given for many leading scientific journals (*California Fish and Game* somehow was not included).

An introduction to scientific illustration will be especially helpful to budding young authors, or even old ones; however, its usefulness should not be overlooked by the wide assortment of harassed editors of scientific publications who are daily faced with the task of properly illustrating their journals.—*John E. Fitch, California Department of Fish and Game.*

Learning to Gun

By John Stuart Martin, Doubleday and Co., Inc., New York, 1963; xiv + 114 pp., illustrated; $4.95.

Written primarily for the beginning bird hunter, this book would be equally interesting and informative for the beginning rifle shooter or experienced hunter. The gunner is told how to shoot and where to find game. It also gives an insight of the joys to expect from the experience of hunting. Mr. Martin has included sections on how to select a gun, how to shoot a gun, type of clothing needed and where to find most upland game and waterfowl. He winds it up by describing the adventure and satisfaction of using a dog as part of shotgun hunting.

Although Mr. Martin has not delved deeply into any one facet of shot-gunning, he has touched many of the salient points. Gunning is covered in an understandable, readable manner using many anecdotes. The text is easily absorbed by the layman and novice.

On the subject of firearms safety, the author has contributed much. The illustration of his own carelessness as a boy and its tragic result is very graphic. However, the selection of photographs on pages 28 and 29 showing "right ways with a gun" is not all in harmony with safe, prudent gun handling. The first two pictures show-

ing a boy leaning his unbreeched shotgun against one fencepost and crossing the fence at the next fencepost definitely illustrate unsafe procedures. The last picture showing the boy going through heavy brush with his finger solidly on the trigger also demonstrates an unsafe maneuver.

All in all, I believe the author has achieved success in composing a book that is an asset to the experienced hunter as well as those who are "learning to gun."—*Dick Laursen, California Department of Fish and Game.*

This Wonderful World of Trout

By Charles K. Fox, Foxcrest, Carlisle, Pa., 1963; 296 pp., illustrated; $7.50.

This is a book about fly fishing. Fashioned into its chapters are accounts of angling in its finest and most rewarding form. Part I consists of 17 chapters presenting a history of dry fly and wet fly tactics, describing the relationship of rods and reels to light leaders, explaining casting techniques, and giving the author's viewpoint of management techniques. Interwoven is the British background which has given fly fishing for trout such a brilliant and rich tradition. Interspersed throughout are accounts of the writer's experiences, and experiences of his cronies "out fishing."

Part II consists of 14 chapters concerning the legend of rising trout. Each chapter is a short story, which for the most part is built around some trick of the trade, and constitutes delightful armchair adventure.

While I cannot say that the brief sections on management and development of streams contribute much knowledge to fishery science, I can heartily recommend this little book to both novice and expert fly fishermen as some of the most entertaining and informative reading I have seen on the subject.—*Leonard O. Fisk, California Department of Fish and Game.*

Limnology in North America

Edited by David G. Frey. University of Wisconsin Press, Madison, 1963; xviii + 734 pp., illustrated; $8.50.

Limnology is a comparatively young science. However, it has developed rapidly, with widespread fragmentation and specialization of interests, thus making it difficult for a worker to remain aware of all the mushrooming facets of the field. This book is an attempt to present a summary of the development and current status of limnology in North America. To accomplish this objective, North America was divided into 19 geographical areas, and at least one active limnologist from each area summarizes the limnology. The geographical areas discussed are: Wisconsin (the Birge-Juday Era and the years 1940-1961); Michigan; New England; Illinois; Middle Atlantic States; Central States; South Atlantic States; Central Gulf States and the Mississippi Embayment; Minnesota and the Dakotas; Mid-Continent States; Rocky Mountain States; Pacific Coast and Great Basin; the American Southwest and Middle America; The West Indies; Western Canada; Ontario and Quebec; The Atlantic Provinces of Canada; the St. Lawrence Great Lakes; Alaska, Yukon, Northwest Territories, and Greenland. In addition, several chapters are included which do not deal with limnology on a regional basis—"The Impact of Reservoirs," "Farm Ponds," "Paleolimnology," "Sanitational Limnology," and, "A History of the American Society of Limnology and Oceanography." In an excellent concluding chapter entitled "The Prospect Before Us," G. E. Hutchinson discusses some of the many limnological vistas in which research is needed. Some of the subjects discussed are: energy budgets of large lakes, chemical limnology, basic productivity, paleolimnology, cyclomorphosis in planktonic animals, and the effects of pollution.

The National Science Foundation gave financial support toward the production of this volume, resulting in an extremely reasonable price for a book of this size and caliber. It contains a detailed index and each chapter ends with an excellent bibliography. The figures and photographs are of exceptional quality.

The only criticism is that, due to the wide and varied backgrounds and interests of the many authors, some topics and geographical areas are more extensively covered than others. Perhaps this will stimulate interest and publication in the areas that are lightly touched upon in this volume.

Editor David G. Frey and 32 of North America's leading aquatic scientists have collectively produced a volume which will become a "must" in the libraries of everyone who has an interest in any of the various limnological aspects of the waters in North America.—*Michael L. Johnson, California Department of Fish and Game.*

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